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THE CABLE RAILWAY
ON THE
NEW YORK AND BROOKLYN BRIDGE.

By G. LEVERICH, M. Am. Soc. C. E.*

1st.—The New York and Brooklyn Bridge, more commonly known as the East River Bridge, is the suspension bridge which spans the East River and connects the cities of New York and Brooklyn. The structure proper extends from the easterly side of Chatham street (recently re-named Park Row) New York, to the westerly side of Sands street, Brooklyn, being on the centre line, from end to end 6 017.33 feet in length. Extensions for switching and storage of cars reach, one in New York over Chatham street, 109.88 feet, and one in Brooklyn over Sands and High streets, 389.22 feet.

I.—DESCRIPTION.

2d.—THE RAILWAY.—The railway proper is from New York Station on the easterly side of Chatham street, to Brooklyn Station on the westerly side of Sands street; passengers being received and discharged only at these points. The railway is double-tracked, of the standard gauge, 4 feet 8½ inches, and laid with steel rails weighing 52 pounds to

* This Paper in an incomplete form, was read at the Annual Convention, July 6, 1887; it is now brought down to May 1, 1888.

the yard; the grade ranges, as shown by profile,* Plate XXVI, from nearly level, to over 3¾ per cent.; the summit in the center of the suspended span, being at a mean height above the track in New York Station of 81.3 feet, and in Brooklyn Station of 56.9 feet. The length of cable within the rails, between the outgoing and incoming sheaves, and therefore available for train service, on the northerly track is 5 446.7 feet, and on the southerly track 5 441.4 feet; a total of $2\frac{1}{16}$ miles.†

3d.—Cable Driving Plant.—The cable is driven continuously in one direction by either of two stationary steam engines, placed underneath the Railway in the Brooklyn Approach, a short distance westerly of Brooklyn Station; the cars are attached to the cable by a roller grip, one on each car, and are run singly or in trains, as the traffic requires; they are switched at the stations from one main track to the other by locomotives, which also are used to haul the trains in the night time when the travel is light; or when from any cause, the cable is temporarily stopped. The cable driving plant consists of steam boilers and engines, winding drums, tension cars, guide and deflection sheaves, bearing and tilting pulleys, and their several attachments. ‡

4th.—The Boilers.—There are six water tube steam boilers of a well-known type; they are set in pairs, and may be operated singly or together; each has 54 water tubes, 4 inches in diameter and 18 feet long, also a cylindrical steam drum 3 feet in diameter running the full length of the boiler, and is rated at 104 horse-power; the grates are 3 feet 10 inches wide and 7 feet long; they have revolving self-stoking grate bars. The boiler house is a detached brick building; the chimney is of brick, double walled up to 33 feet from the top; its base is 15

* This is the construction profile; the grades shown for the suspended structure being those which were intended it should have at a temperature of 90° Fahr. The superstructure rises and falls inversely with the temperature and the grades on it vary considerable from those shown.

† During the design, construction and operation of this Railway, the engineers principally in charge were: Washington A. Roebling, Chief Engineer to July 1, 1883, who was then succeeded by Charles C. Martin, formerly Principal Assistant Engineer, since Chief Engineer and Superindent; William H. Paine, Assistant Engineer to January 1, 1886, and now Consulting Engineer; and Samuel R. Probasco, now First Assistant Engineer. The writer was not engaged in this department until October 4, 1883.

‡ Letters Patent of the United States, upon portions of this plant, have been granted to William H. Paine, as follows:

173 329—Device for connecting Cars with moving Ropes; February 8, 1876.
296 602—Cable Railway Appliances; April 8, 1884.
296 603—Auxiliary Switching Apparatus for Cable Railways; April 8, 1884.
296 604—Gripping and Brake Mechanism for Cable Railways; April 8, 1884.
296 605—Roller Grip for Cable Railways; April 8, 1884.
296 606—Automatic Connector and Disconnector for Grips of Cable Railways; April 8, 1884.
331 237—Cable Supporting Sheaves for Cable Railways; November 24, 1885.
331 238—Hand Mechanism for Operating Grippers for Cable Railways; November 24, 1885.
331 239—Rope Driving Machinery; November 24, 1885.
371 095—Gripper for Cable Railways; October 4, 1887.

feet 4 inches square, and its height from foundation to top, 139 feet 10 inches; the flue is 5 feet 3 inches square at the base, and 5 feet 6 inches square at the top; its height is 129 feet 4 inches. A platform elevator lifts the ashes from the boiler house floor, about 15 feet up to the level of the adjacent sidewalk; it is operated by a steam winding engine, with cylinder 6 inches in diameter and 7 inches stroke. The chimney drafts are controlled by an automatic damper regulator, whereby the boiler pressure, under all the changing loads imposed on the engines, is kept close to the mean limit, or about 76 pounds. The feed water is supplied to the boilers by a direct acting steam pump with steam cylinder 10 inches and pump cylinder 6 inches in diameter; the stroke is 12 inches. The exhaust steam passes through a vertical tubular feed water heater, 3 feet 4 inches in diameter and 11 feet high. Besides furnishing steam for the engines of the cable driving plant, these boilers supply one or more of three electro-lighting engines, each of about 50 horse-power, and one workshop engine of about 20 horse-power; also in cold weather for heating Brooklyn Station, the office building and the workshops.

5th.—The Engines.—For the cable driving plant there are two horizontal steam engines; the cylinders are 26 inches in diameter and the stroke 48 inches; the fly-wheels are 18 feet in diameter and weigh 30 000 pounds. These engines have a specially devised automatic cut-off valve gear; they are connected to the outer ends of the main or drum shaft and drive it by jaw clutches, but one engine being operated at a time. At mean speed they make 57 revolutions, or their pistons move 456 feet per minute. The position of the engines, drums, the Brooklyn tension car and the Brooklyn sheaves, is shown in Plates III and IV.

6th.—The Drums.—There are two large drums, 12 feet in diameter with 26 inches face, and one small drum, 5 feet in diameter, with 31½ inches face. There are four semi-circular grooves, originally ¾ inch deep, in each of the large drums; the shafts are placed in vertical planes 17 feet apart, and are inclined in different directions, 1 in 128 from the horizontal, so that the grooves at the bottom of the drums, are opposite each other and at the top, the second, third and fourth grooves of one or the driving drum are opposite respectively the first, second and third grooves of the other or driven drum; thereby the lines of cable as it is wound around the two drums, pass fairly from one set of grooves to the other. The small drum is placed midway between the large drums, and fills nearly or quite the entire space, except opposite the grooves, where its face is cut away; it runs loose on the main shaft. On one side of the small drum and close to it, is keyed to this shaft a pinion with 35 teeth and pitch circle 5 feet in diameter, which gears into a wheel keyed on the shaft of and bolted to the driving drum; this wheel has 84 teeth and pitch circle 12 feet in diameter; the pitch of the teeth is 5.39 inches and their face length 12 inches. At mean speed the large drums revolve 23¾ times per minute, whereby the mean speed of the cable would be 895.35

feet per minute or 10.17 miles per hour, were the grooves unworn and there was no slipping on the drums; the mean speed of the cable is generally taken at 880 feet per minute or 10 miles per hour. The drums and their bed plate are shown in Plates III–V; the gear-wheel and pinion being omitted from all but the elevation, Plate III.

7th.—The Cable.—The cable is made of crucible steel; it is about 11 500 feet long; when new it was 1¼ inches in diameter, and weighed 3½ pounds to the foot length. It contains 114 wires, each nearly $\frac{1}{10}$ inch in diameter, laid in six strands around a central strand of hemp. Beginning at the point where the cable first reaches the drums, its course about them is: down, one fourth way around the driving drum, half way around each drum successively three times, and up one fourth way around the driven drum; from the drums it passes over a guide sheave, around the sheave of the Brooklyn tension car, under another guide sheave, up through the arch of Brooklyn Approach and over the outgoing sheave near Brooklyn Station to the northerly track of the Railway; along this track to the incoming sheave in New York Station; thence down under the Railway, around this and two other sheaves and under the footway to the New York tension car; around the sheave of this car, over the outgoing sheave in New York Station, up to the southerly track of the Railway; thence along this track to the incoming sheave near Brooklyn Station, over this sheave and down through the arch of Brooklyn Approach to point of starting.

8th.—The Tension Cars.—To prevent the cable, under whatever traction resistance it has to overcome, from slipping on the drums, as well as to take up whatever elongation there may be in the cable at the rear of trains from Brooklyn Station, a certain stress must be maintained in the cable as it leaves the drums, and this is done by the Brooklyn tension car. To take up the elongation which, more or less, runs before trains from Brooklyn after they pass the summit, as well as that which may follow trains from New York until they reach the summit, the New York tension car is provided. Each of these cars also act when the length of cable is increased or lessened by changes in atmospheric temperature. The tension cars are shown in Plates IV and IX; each has a cast iron frame, which rests on four flanged wheels and carries a sheave; that in Brooklyn being vertical and running in two pillow blocks, and that in New York being inclined and running in one long journal box. The cars traverse an ordinary railway track of 3 feet gauge, on a grade of 20 per cent. in Brooklyn and of 46 per cent. in New York. To prevent the New York tension car from being overturned by the side strain to which it is subjected, there is a third rail, close underneath the sheave, above and parallel to the main track, traversed by a pair of small guide wheels, attached to the tension car frame; this rail and the guide wheels are not shown in the Plates. The cars are weighted, and to relieve that in Brooklyn from an undue load on its wheels, an additional

weight was recently attached by means of a wire rope and two pulleys, so as to oppose directly the forward movement of the car. The initial stress on each line of cable, running to and from the car, thereby caused is in Brooklyn about 1 800 pounds, and in New York about 1 500 pounds. At times an excess of train loads running down grade may increase the back haul on the tension cars much above these limits. To prevent too great movement then, a barrier is kept before each car against which it will bring up; also on the Brooklyn tension car, as shown in Plate IV, a weighted brake is hung over each wheel, so as to yield readily when the car moves down grade and to resist when the movement is in the contrary direction.

9th.—The Sheaves.—The sheaves, as first used, are shown in Plate X. They were cast in one piece with hubs split into three parts; a flat wrought iron band was shrunk on each end of the hub, which was then bored, the shaft inserted and keyed fast. The rim including the groove, was turned, and the cable ran in contact with the metal surface. Some of the sheaves were replaced by others made as shown in Plate XI. These were in two parts, the rim and the arms; the bearing surfaces were finished and the parts bolted together by turned bolts driven into reamed holes; the groove for the cable was solid, however, as before. The two sheaves shown in Plates IX and XVII, as first made were similar to those shown in Plate X, except that the rim was in parts bolted together; they enclosed in the groove, which was dovetailed, a packing of seasoned hickory blocks, boiled in linseed oil, placed with fibers radial and then turned out to receive the cable. For these packed sheaves were substituted others made as shown in Plate XII, differing from that shown in Plate XI, in having the rim divided as just described, and packed with leather and india rubber belting, placed radially in the proportion of ten thicknesses of leather to one of india rubber. As shown in the Plates, the sheaves generally have a shaft, running at each end in a pillow block, and are supported by cast iron frames bolted to the masonry; the exceptions are; the New York tension car sheave as already noted, and the horizontal sheave under the footway in New York Station, which runs loose on a fixed shaft. Some of these journals are 3 and others 4 inches in diameter; those which run in pillow blocks are 6 inches long. The pillow blocks are shown in Plates XIII and XIV; those first used were in two parts and babbitted; some of these were replaced by other pillow blocks, having brass bearings, cut into four parts and arranged to adjust for wear in two directions.

10th.—The Pulleys.—The cable between the rails, is supported by fixed and tilting pulleys, shown in Plates XV and XVI; in each the groove for the cable is packed with leather and india rubber belting placed radially; a larger part being india rubber. The pulleys are cast in one piece, and in the solid groove the packing is laid piece by piece as closely together as may be; the small spaces left are filled and the

outer grooved surface coated with coaltar pitch, applied hot. Other packings, as of hemp, and of india rubber in one mass filling the groove and vulcanized in place, have been tried, but were unsatisfactory. The fixed pulleys are on a steel shaft which runs in two bearings; the journals are 1 inch in diameter and 1¾ inches long; the journal boxes are in two parts, the upper or cap being hinged to the other and fastened by a self acting latch, recently attached and not shown in the Plate; the bearings are of babbitt metal and do not fill the entire length of the box; the space left forms a reservoir for oil, which is kept in by a circular fillet fitted into a groove around the shaft near the inner end of the journal. The pulley frames are bolted to the cross ties of the track, the fixed pulleys being placed generally 30 feet apart; their position on the suspended structure is shown in Plate VII, and in relation to the cross ties and rails, it elsewhere is substantially the same.

Generally the cable is 3 inches above the rails; at the two places where the grips are attached, it must be raised from 4½ to 8 inches higher; for which purpose the tilting pulleys, put 12 feet apart in New York Station and 6 feet apart near Brooklyn Station, in number sufficient to serve the longest train run, are employed. These pulleys run loose on one end of a horizontal pin, which is at the free end of a counter balanced lever; on the other end of this pin is an idle flat faced wheel, against which the inverted bent rail, forming a part of the grip mechanism now used, shown in Plate XXI, and to be described, bears when the grip is to take hold of the cable. The lever is pivoted at the fixed end and is placed so that the pulley is on the same side as where the cable runs. The tilting pulley shown in Plate XVI is as it was first made; the lever was weighted so as normally to hold the cable somewhat higher than its place in the grip and as the cars passed over, the lever was depressed by the inverted rail, leaving the cable suspended. Now, the shafts to which the levers are attached are extended to one side of the track, and by cranks and a long jointed connecting rod, with a coiled spring interposed at each crank, all the pulleys in one place are united together, and by other cranks and rods, a workman detailed for the purpose, from one point, elevates the pulleys and the part of the cable which is supported by them and underneath an outgoing train, until the grips take hold and then he allows the pulleys to fall back to their lower position. Recently the weights have been replaced, each by a coiled steel spring, so attached to the lever as to nearly balance it and its parts during the entire movement up and down.* The hubs of the tilting pulleys are made hollow; the enclosed space serves as an oil reservoir for lubrication.

11th.—THE CARS.—When the Railway was first operated, it had 24 passenger cars; one half being 36 feet 4 inches long, weighing 8½ tons, and one half 48 feet long, weighing 10 tons each, with doors at the ends

* Letters Patent of the United States, upon this improvement, have been granted to Origen C. Crane, as follows:

383 703—Cable Supporting Sheave for Cable Railways; May 29, 1888.

only. Afterwards the shorter cars were discarded, side doors were introduced, and from time to time as required, other cars, stronger and heavier, were procured, until now there are 44 in use. These are all essentially alike; one of the last purchase, partly shown in Plate XXIV, may represent the whole: it is 48 feet 10 inches long between draw bar or coupler pins, and 39 feet 6 inches from end to end of body, 9 feet 7 inches wide out to out, and 13 feet inches 8 high from the track to uppermost point; with a 4 wheeled truck at each end, 32 feet 5 inches apart from center to center of truck pins, and axles 5 feet apart. The wheels are of paper, steel tired; they are 30 inches in diameter, with treads 4 inches wide. The unloaded car weighs 16¾ tons. It has double sliding doors at each end with openings 3 feet 5 inches wide, and single slidings doors, one in the middle of each side, with 2 feet 8 inches opening. There are 40 barred seats placed in line along each side, and an aisle 4 feet 8 inches wide between the seats; with the seats, aisle and platforms fully occupied, 150 persons have been carried. The car is lighted by eight argand lamps, arranged in three clusters and burning mineral oil. In cold weather, the car is heated by one hot water heater, with two lines of wrought iron pipes 1¼ inches in diameter under each line of seats.

12th.—THE GRIP FIRST USED.*—As employed on the Railway, the grip consists essentially of the sheaves which grasp the cable, the brakes which prevent the sheaves from revolving, the levers by which the pressure is applied and the frame which holds the moving parts. The grip first used, shown in Plate XX, is described as follows: There are four sheaves placed in pairs, so that the cable is gripped between each pair; each sheave runs loosely on a short, fixed pin and has a heavy grooved rim with cylindrical inner surface, against which the brake presses; this rim is in two parts bolted together and holds in a dovetailed groove a packing of leather and india rubber belting in alternate pieces placed radially; the packing projects well out from the rim and is grooved to receive the cable. There are also four brakes, one for each sheave, of hard wood and with a curved outer face fitted to the inside of the rim of the sheave; each brake is held by a lever and the four levers are connected to the two operating levers, which are so pivoted that their short arms form a toggle. The frame is made up of flat wrought iron bars, bolted together and also hinged, so as to permit

* In a "Communication from the Chief Engineer in Regard to the Method of Steam Transit over the East River Bridge, made to the Board of Trustees, March 4, 1878," is the following: "For the circulating system, the engine is run continuously in one direction; the rope is spliced endless, and the tracks at the termini are connected by a short switch, the empty cars being transferred from one track to the other by a horse or steam power. For securing the car to the running rope, many patent contrivances exist, but as there are no stoppages on the way, the simplest method will be—a short piece of manilla rope, one end of which is fastened to the car, then taking a half hitch around the wire rope, the driver holds one end with one hand and the brake with the other, and thus has full control over the car. This was in use many years ago on the old Portage Railway over the Alleghany mountains, but for a high rate of speed its application might be somewhat doubtful."

the necessary movements of the sheaves and brakes. Adjustments to take up wear and restore the proper relative positions of the operating parts are made by hand screws placed in the connections of the frame. The long arms of the operating levers are moved towards each other or apart, to close or open the grip, by means of a small endless cable, one line being attached to the end of each lever; this cable is underneath the car, and at each platform a sprocket chain forming a part of the cable is wound around a sprocket wheel, which is on the lower end of the brake shaft. The arrangement of operating levers, cables and winding gear is shown in Plates XXII and XXIV. It will be seen, that in operating the grip, as it is closed the sheaves are brought into contact with the cable and revolve at cable speed; the car being at rest, the brakes force the sheaves together with increasing pressure, which, transmitted to the sheaves from the brakes, develops a frictional resistance tending to prevent the sheaves from revolving, and this continues until such resistance in the four sheaves exceeds the tractive resistance of the car, when the sheaves cease to revolve and the car moves at cable speed. The grip is bolted underneath the car floor, as shown in Plate XXIV, about midway between the trucks, with the plane of the sheaves inclined 22 degrees from the horizontal, and one side of the frame is fixed by adjustable stay rods, reaching down from the car bottom. A trip gear was provided, shown in Plate XX, for releasing the cable without moving the operating levers; it was worked either by hand or by a third lever, which came into contact with a stop fixed along side of the track, at a point where the cable should be dropped.

13th.—The Grip now used.—For the grip above described, was substituted the one now employed, shown in Plate XXI, and differing from the first, in having comparatively long shafts for the sheaves, a strong rigid frame for the operating parts, and a self adjusting device whereby the relative position of the pieces subject to wear, is automatically preserved; a packed vise grip and means for grasping the cable at the tilting pulleys, while the car is in motion or at rest, were added, and the trip gear was omitted. The sheaves are each keyed to one end of a steel shaft which runs in two closed bearings, so arranged that when a sheave is to be taken out for repair or other purpose, it and its shaft may be quickly removed and replaced by another, if need be, in working condition. The main frame is in two parts, each hinged in a common line parallel to the cable, close under the car floor, one part hanging on each side of the cable. The sheaves, each are carried by a small frame, hinged from its part of the main frame, in a line parallel to the sheave's shaft; this small frame has a limited movement, opposed by a coiled spring, which tends to force the sheave away from its brake; each of the four brakes is held by a projecting end of the main frame; the vise grip is in two parts, each being on the inner face of the lower bar of a part of the main frame; it is packed in the same manner as are the

sheaves. The uppermost part of the main frame, that from which the operating levers project, is fixed in position by adjustable stay rods; the movable part is connected to the levers by a coarse threaded screw, which is turned by a rachet wheel and pawl. It will be observed, that as the grip is used, the packed grooves in the sheaves are slowly compressed and worn, thereby permitting when the grip is closed, the sheaves to come more nearly together, and the short arms of the operating levers to approach more closely to a straight line; and as this continues the pressure on the packed surfaces increases rapidly. Such action is prevented, when as the grip is closed, a certain position of the levers in approaching each other is passed, by the pawl engaging with a tooth of the ratchet wheel, then as the levers are separated, the screw is turned slightly, which brings the sheave surfaces and the levers to their former and normal relative positions. The frames are of cast steel, with fixed joints, and stiffened where the greatest stresses are resisted. The wise grip which grasps the cable only as the frames and the sheave packings yield, is intended to take full hold after the sheaves cease to revolve and the car is moving at cable speed; the trains start from the Stations on a descending grade, and this increase in the tractive power of the grip was thought to be needed when they reach the ascending grade. Suspended from the fixed part of the frame, is the bent inverted rail, also of cast steel, which comes into contact with the flat-faced idle pulleys on the tilting pulley frames; to prevent the cable from being lifted above the grip sheaves when these pulleys are elevated, a small stop pulley is put near each end of this rail; these pulleys are made up of flat rings of leather and india rubber, forced on to a cast iron spool, which runs loosely on a fixed pin.

The packings for the grip are cut in a punching machine driven by power, from the material in sheets, with a sharp die, shaped to fit the contour of the piece; the pieces are put together under pressure, and well tacked with wire nails, as piece after piece is laid on; the packings so formed are kept in stock, and when used they are forced into place. For the sheaves, the packing is made up in two equal sections, and when in the sheaves the material has been compressed about 2½ inches in a circumference of 15 inches mean diameter, so that as the leather tends to swell from moisture absorbed in wet weather and shrink as this evaporates, the elasticity of the india rubber keeps the packing intact and the pieces closely in contact. As the grooves wear deeper, the projecting parts are turned off so as not to interfere with the closing of the grip, and if necessary the groove is also trued; thus a large part of the material is finally used before the packing is thrown aside and a new one put in the sheave.

14th.—The Brakes.—By the usual arrangement of levers and rods, shown in Plate XXIV, a brake is applied to each car wheel; the whole being operated by hand or a partial vacuum. A hand wheel and

shaft on each platform, by means of a lever and clutch (see Plate XXII) are connected with either the grip or brake gear; the sprocket wheel which opens and closes the grip, and the cylinder which winds the brake chain, each being loose on the hand wheel shaft; the one or the other being fixed for the time, as this shaft is elevated or depressed by the lever. For the vacuum apparatus, there is a diaphragm chamber on each truck and a reservoir underneath and attached to the car body. A chain connects each diaphragm with a brake lever on the truck and pipes connect the two diaphragm chambers with the reservoir; these pipes run to each end of the car, where by means of a three way cock under the platform and a small hand lever, pressure is applied to the brakes or released. At first the reservoir was exhausted by connecting it with a vacuum ejector on a locomotive; this was done while the car in its trips, was stopping at Brooklyn Station; afterwards a pump, shown in Plate XXV, was put on, and each car maintains the requisite tension in its reservoir. The pump is attached to the underside of one truck and is driven from a car axle by an eccentric; it is single acting and has a trunk piston; the cylinder is 5 inches in diameter and the stroke 5½ inches long. By this pump, in running the car less than 1 000 feet after the brakes have been applied, the tension in the reservoir is restored, and a working vacuum of from 12½ to 13½ pounds readily maintained, sufficient for all demands. Ordinarily the tension in the reservoir is reduced by applying the brakes, from 2½ to 3 pounds.

Before this attachment was put on, the vacuum was reserved for emergencies, and only applied then, whenever the hand brakes failed, or occasionally to determine that the parts were in working order; now the vacuum is generally used in operating the brakes. It will be noticed the mechanism described is not in duplicate; the brakes, levers, rods and their connecting parts being common to the two brake systems; that each car has its own apparatus which is operated independently of that on other cars in a train; and that the brakes cannot be applied until the grip is released.

15th.—The Locomotives.—To haul the trains to and from the storage platform or from one main track to the other at the Stations, over the Railway during the day whenever the cable from any cause is not running, and late at night when the traffic is lightest and the cable is stopped, four-wheel tank switching locomotives are used; that is, they are without tenders; the entire weight, including that of the coal and water carried, being on the four driving wheels. At first there were two, each weighing, when loaded, 9 tons, with steam cylinders 9 inches in diameter and 14 inches stroke, driving wheels 36 inches in diameter, and wheel base 5 feet 9 inches long; and two others, weighing, when loaded, 13 and 14 tons, with steam cylinders and driving wheels as before mentioned, and wheel base 6 feet long. As the traffic increased

and longer trains were run, these were replaced by heavier locomotives. Now there are employed three, each weighing when loaded, 21½ tons, with steam cylinders 11 inches in diameter and 16 inches stroke, driving wheels 38 inches in diameter and wheel base 6 feet long; and two others, weighing when loaded, 22 and 23 tons, with steam cylinders 12 inches in diameter and 16 inches stroke, the driving wheels and wheel base being as last mentioned. Four of these locomotives are in constant use; when necessary one will haul a train of two loaded cars, at cable speed, over the railway. The locomotives and cars are all fitted with the automatic car coupler, shown with the link, in Plate XXIII. The sidings and connecting lines are laid with Lorenz or point switches; generally at each Station, they are operated from one place or switch house.

16th.—The Auxiliary Cable Plant.—To switch trains in New York Station from one main track to the other, a pair of continuous cables ⅜ inches in diameter were used for several months after the opening of the Railway, one cable along each of the two switches. The hauling lines of these cables, between the tracks, were placed 8 inches apart; that is, 4 inches on one or the other side of the centre line of track. The driving plant is shown in Plate XVII; the arrangement of the cables and their pulleys, and the position of the switches are shown in Plate VIII. Each cable was driven by a pair of winding drums 4 feet in diameter, which were loose on the shafts of the two sheaves under the northerly main track; a pair of drums on each side of the sheaves. The main cable so passed around these sheaves, that they revolved in opposite directions; the drums were driven by means of friction clutches, which were engaged or disengaged by a system of levers and rods, terminating at a point where an attendant could operate it; one drum being clutched to its sheaves, would haul the cable in one direction and the other drum of the pair being clutched to its sheave would haul the cable in the contrary direction; but one drum driving at a time and the other of the pair running loosely, the two clutches being operated by one lever. The friction clutch used consisted of a steel hoop attached to the driving shaft, 4 inches wide, 1½ inches thick and 42½ inches in diameter; this was cut apart at one place, and between the ends thus formed a wedge was forced outward by means of a toggle, so that the hoop was expanded into close contact with the inside projecting cylindrical surface of the drum cylinder. The auxiliary cables ran at a speed of 4 miles per hour; to each a small grip car was permanently attached by a vise grip; each car ran to and fro on its own line of track as the drums were operated, and the trains to be switched were hauled by these cars. For the auxiliary cable plant thus described was substituted that shown in Plates XVIII and XIX, differing from the first in having the drums entirely detached from the sheaves, except when the clutches were engaged; providing a shaft for each drum, with large bearings and adjustable pillow blocks; and a frame which allowed renewal of the

several parts, piece by piece, without interfering with the use of the remaining plant; also other modifications for convenience and utility. So far, this plant has not been put in operation.

II.—TRAFFIC AND OPERATION.

17th.—Train Service.—The number of trains run daily and of cars in each train, has steadily increased since the Railway was first operated; the traffic offered however, fluctuates greatly; being affected by the occasion and the weather, as well as the time of day, the day of the week and the season. The first train—of one car—ran over the Railway, August 8, 1883; the following day five trips were made, and passengers were first taken September 24. Two-car trains were run October 28, 1883, and three-car trains September 15, 1885. Trains were first run during the busy hours morning and evening, on 1½ minutes headway, March 5, 1885, and on 1¾ minutes headway, March 2, 1886. Experimentally, 3 three-car and 10 two-car trains were run on 1¼ minutes headway, 1½ hours in the morning and 2 hours in the evening, September 27, 1886. Usually however, the minimum headway during the day's run is 1½ minutes. Table I, compiled from the train dispatcher's daily record, giving the number, order and headway of trains sent out from Brooklyn Station during the days mentioned, exhibits fairly the past and present operation of the Railway; it being noticed that the same trains were also sent out and in the same order from New York Station.

Interruptions and delays in handling the traffic on a railway like this, must necessarily from time to time occur; a summary of the causes and extent of such during the four years and five months ending April 30, 1888, or nearly the whole term the railway has been operated, is given in Tables II and III; the times therein recorded being those during which travel was entirely stopped; usually when the delay is likely to be unduly prolonged, trains are run in the intervals by locomotives. By these Tables, it appears that of the total time lost by delays in the terms referred to, that due to the cable system decreased from about 77 per cent. for the five months ending April 30, 1884 to about 24 per cent. for the year ending April 30, 1888; and for the whole time covered by the Tables, it was about 44 per cent. In Table III it is intended to show at a glance, how inconsiderable the average loss from delays at any time has been to the single passenger; it will be seen that this loss has steadily decreased since the Railway was first opened to traffic.

The Railway has been operated with great safety to passengers and trainmen; the only accident which caused serious injury to either, occurred on a wet and sleety morning, December 5, 1885. A train from Brooklyn to New York dropped the cable at the Brooklyn pier; the following train ran to within 100 feet of it and stopped, the brakes were released and the train was permitted to run back on the down grade with too great speed; it collided with a third train, breaking platforms and

TABLE I.—NUMBER AND HEADWAY OF TRAINS.

Tuesday, April 29, 1884. From 5 A.M. to 12 50 A.M. 19 hours, 50 minutes.				Tuesday, April 27. 1886. From 12 A.M. to 12 A.M. 24 hours.				Tuesday, May 1, 1888. From 12 A.M. to 12 A.M. 24 hours.			
Number of trains.	Number of cars in train.	Headway.	Power employed.	Number of trains.	Number of cars in train.	Headway.	Power employed.	Number of trains.	Number of cars in train.	Headway.	Power employed.
		Min. sec.				Min. sec.				Min. sec.	
13	1	5 — 0	Cable.	12	1	4 — 0	Cable.	12	2	4 — 0	Cable.
15	"	4 — 0	"	17	"	15 — 0	Loco.	9	"	15 — 0	Loco.
5	2	3 — 0	"	16	"	4 — 0	Cable.	8	1	" "	Cable.
6	"	2 —30	"	9	2	3 — 0	"	16	2	4 — 0	"
53	"	2 — 0	"	94	"	} 1 —30	"	9	3	3 — 0	"
6	"	2 —30	"	46	3		"	140	"	1 —30	"
10	"	3 — 0	"	24	"	} 2 —30	"	138	"	3 — 0	"
7	"	4 — 0	"	18	2		"	72	"	1 —30	"
54	"	5 — 0	"	90	"	3 — 0	"	18	"	3 — 0	"
15	"	4 — 0	"	73	"	} 1 —30	"	10	"	4 — 0	"
20	"	3 — 0	"	37	3		"	55	2	" "	"
32	"	2 —30	"	20	2	3 — 0	"				
27	1	3 — 0	"	53	"	4 — 0	"				
20	"	4 — 0	"	6	1	" "	"				
46	"	5 — 0	"				"				
329 trains, 537 cars.				515 trains, 1 092 cars.				487 trains, 1 353 cars.			

ends from one car, one platform and end from another car, and other platforms more or less. The cars were crowded, passengers being on all but the front platforms of the trains, and two persons were seriously injured, one being a brakeman. The cars had to be separated by force before one of the injured was released; he, a passenger, having a foot crushed by being caught between two platforms, sliding one over the other. The accident was due to the brakemen on the middle train (one of whom was so badly hurt) becoming confused and not applying the brakes, in time. Collisions sometimes happen, of which this is a rare instance. About 6·30 o'clock P. M. February 12, 1886, just after an incoming train at Brooklyn Station was moved from the platform, the locomotive hauling it, jumped the switch. The following train, crowded with passengers, ran into the first with considerable shock, but without greater injury to the passengers, than a few bruises; the third train was brought up in time. This accident was due to the enforced stoppage of the first train.

18th.—Passengers Carried.—The number of passengers carried each calendar month, from the opening of the Railway, to and including April, 1888, is given in Table IV; it may be stated that the fare was five cents until March 1, 1885, when it was reduced to three cents, or to ten tickets for twenty-five cents. By this Table, it appears that the number has increased in the four years ending with September, over 244 per cent., and ending with February, over 211 per cent. An interesting local inquiry is how long and at what rate, will this traffic continue to increase. So far as a reference to the past traffic will aid in considering a reply, the number of passengers carried in each period of twenty-eight days, or lunar month, as exhibited by the diagram on page 82, will serve better than the data given in Table IV.

During the day of 24 hours, the traffic over the Railway ebbs and flows in an irregular and greatly varient tide; this appears from the number of cars in the trains run and the headways; the loads on the trains are heavier in the morning on those from Brooklyn, and in the afternoon on those from New York; for a part of each time, the cars moving one way will be densely crowded, and those moving the other way will be perhaps not one-fourth full; during other intervals, the travel in the two directions may be nearly equal. The number of passengers carried each day of 24 hours is regularly taken and recorded; at certain times, the number during specific hours has been counted, and from the data thus obtained Tables V and VI were collated, showing the fluctuation and relative proportions of daily travel at different periods. The mean per cents. given in Table V, correspond quite closely to similar per cents. for the several days mentioned. From the Table, it will be seen that about 82 per cent. of the total traffic is carried in the 12 hours from 7 o'clock A.M. to 7 o'clock P.M., and about 22 per cent. in one-sixth of this time, the maximum morning and evening hour. The number of passengers each way, carried each hour of two days, about 18 months apart, is given in Table VI, and is for the even hour as noted in the first column; the maximum number is 10 068 passengers carried from Brooklyn to New York, between 7 and 8 o'clock A.M., November 29, 1887. During the morning and evening rush, when the travel for a short time is greatly concentrated, this may be exceeded; thus in the sixty minutes between 5–30 and 6–30 o'clock P.M., Monday, November 18, 1887, 12 160 passengers from New York to Brooklyn were carried.*

* As the stations and train platforms are now arranged, passengers may crowd upon the latter, until the available space near to the outgoing train is closely occupied; and consequently during the rush hours a few trains may be overloaded. At the time above mentioned, trains of three cars each on 1½ minutes headway or 120 cars per hour were running; whence if the movement of passengers to the trains were regulated and only so many as could be comfortably carried, admitted at one time to the platform, each car would have had but about 100 passengers, there need not have been any crowding, and no one would have been delayed over one headway.

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TABLE II.—CAUSES AND EXTENT OF DELAYS.

Term.	5 months ending April 30, 1884.		Year ending April 30, 1885.		Year ending April 30, 1886.		Year ending April 30, 1887.		Year ending April 30, 1888.		4 years and 5 months ending April 30, 1888.	
Causes of Delays.	No.	Time lost.	No.	Time lost	No.	Time lost.	No.	Time lost.	No.	Time lost.	No.	Time lost.
		H. M.		H. M.		H. M.		H. M.		H. M.		H. M.
Auxiliary cable car failed	5	0—56	..	.....	...	.....	..	.....	..	.....	5	0—56
" drum stuck	..	.....	1	0—35	...	.....	..	.....	..	.....	1	0—35
Cable dropped at tilting pulleys	..	.....	..	.....	1	0— 7	..	.....	..	.....	1	0— 7
" elsewhere	12	1—52	7	1—29	...	.....	1	0— 3	..	.....	20	3—24
frozen fast	1	0— 4	..	.....	...	.....	..	.....	..	.....	1	0— 4
not caught by grip	..	.....	..	.....	...	.....	6	0—24	6	0—19	12	0—43
slipped on driving drum	..	.....	1	0—35	...	.....	..	.....	..	... ..	1	0—35
thrown from tilting pulleys	..	.....	..	.....	6	0—27	5	0—30	16	0—42	27	1—39
Driving engine overloaded	..	.....	..	.....	...	.....	..	.....	4	1—27	4	1—27
stopped by hot bearing	3	0—59	1	0— 2	1	0— 5	..	.....	1	0— 7	6	1—13
" from other causes	1	0— 5	1	0— 6	...	.....	..	.....	1	0—10	3	0—21
Grip frame or gear, failed	5	0—31	3	0—30	14	1—31	4	0—12	1	0— 3	27	2—47
out of place	..	.....	..	.....	14	0—44	1	0— 3	2	0—14	17	1— 1
sheaves worn	1	0— 5	1	0— 8	1	0—10	..	.....	..	.....	3	0—23
not closed	..	.....	1	0— 5	37	2—38	..	.....	..	.....	38	2—43
" released	1	0—14	2	0—58	1	0— 5	3	0— 6	..	.....	7	1—23
slipped, cause not stated	..	.....	..	.....	6	0—37	3	0—13	..	.....	9	0—50
Total, caused by grips	7	0—50	7	1—41	73	5—45	11	0—34	3	0—17	101	9— 7
Tension car derailed or out of order	..	.....	..	.....	...	.....	2	0—35	..	.....	2	0—35
Total, caused by entire cable system	29	4—46	18	4—28	81	6—24	25	2— 6	31	3— 2	184	20—46
Accident to passenger	..	.....	..	.....	...	.....	..	.....	1	0— 5	1	0— 5
Block signal, out of order	..	.....	..	.....	2	0—12	..	.....	..	.....	2	0—12
Brake gear failed	1	0— 8	..	.....	3	0— 6	7	0—20	4	0—13	15	0—47
" frozen fast	..	.....	..	.....	2	0— 8	2	0— 9	..	.....	4	0—17
vacuum leaked	..	.....	..	.....	...	.....	1	0—25	..	.....	1	0—25
Brakes not released	..	.....	..	.....	2	0— 6	1	0— 4	..	.....	3	0—10
Car axle broken	..	.....	..	.....	...	.....	..	.....	1	0—15	1	0—15
wheel flattened	..	.....	..	.....	..	.....	1	0— 2	..	.....	1	0— 2
Collision, switch misplaced	..	.....	1	.....	...	.....	..	.....	1	0— 2	1	0— 2
from other causes	3	0—36	..	0—10	6	1— 6	2	0—17	1	0— 3	13	2—12
Derailment, from snow and ice	..	.....	..	.....	...	.....	..	.....	1	1—25	1	1—25
" switch misplaced	..	.....	4	.....	4	1—40	3	0—59	3	0—46	10	3—25
" " not adjusted	..	.....	6	1—57	4	0—23	8	2—53	16	2— 7	32	7—20
cause not stated	1	0—30	..	0—43	16	5— 9	..	.....	..	.....	23	6—22
Drawbar broken	..	.....	..	.....	...	.....	18	0—47	14	0—28	32	1—15
caught on truck	..	.....	..	.....	...	.....	..	.....	1	0— 3	1	0— 3
pulled out	..	.....	..	.....	1	0— 4	4	0—12	..	.....	5	0—16
Locomotive, out of order or steam	1	0—10	..	.....	1	0— 5	4	0—47	..	.....	6	1— 2
Train too long or ran too far	..	.....	..	.....	...	.....	1	0— 4	1	0— 4	2	0— 8
ran into bumper	..	.....	..	.....	...	.....	..	.....	1	0— 3	1	0— 3
stalled on crossing	..	.....	..	.....	...	.....	..	.....	1	0—14	1	0—14
uncoupled	..	.....	..	.....	...	.....	..	.....	1	0— 6	1	0— 6
Total from causes independent of cable system	6	1—24	11	2—50	41	8—59	52	6—59	47	5—54	157	26— 6
Total from all causes	35	6—10	29	7—18	122	15—23	77	9— 5	78	8—56	341	46—52
Total preventable at the time	4	0—40	10	3—22	52	5—57	16	1—47	22	1—53	104	13—39

TABLE III.—NUMBER OF PASSENGERS WHO FROM DELAYS, COLLECTIVELY LOST ONE SECOND, DURING THE TERM MENTIONED.

Term.	5 months ending April 10, 1884.	Year ending April 30, 1885.	Year ending April 30, 1886.	Year ending April 30, 1887.	Year ending Apr 1 30, 1888.	4 years and 5 months ending April 30, 1888.
Passengers carried.....	3 475 420	10 503 237	21 300 866	26 036 464	29 021 571	90 347 558
Delays	Number of passengers.					
Due to the grip.....	825	1 733	1 029	12 763	28 451	2 753
" entire cable system.....	144	653	925	3 444	2 658	1 208
" remaining railway service.....	491	1 030	659	1 036	1 366	962
" entire railway service.....	112	400	385	796	902	536
Preventable at the time.....	1 031	867	994	4 056	4 281	1 838

TABLE IV.—PASSENGERS CARRIED EACH MONTH.

	1883-84.	1884-85.	1885-86.	1886-87.	1887-88.
October.....	477 700	816 220	1 958 495	2 317 392	2 635 617
November.....	561 520	797 640	1 868 088	2 270 026	2 514 184
December	600 440	898 800	1 873 316	2 322 373	2 620 609
January.....	663 840	889 420	1 828 517	2 321 896	2 521 786
February.....	723 740	904 630	1 778 584	2 123 129	2 436 694
March..	735 180	1 353 557	2 084 715	2 433 069	2 488 892
April....	752 220	1 402 390	2 007 498	2 379 360	2 593 104
May.....	766 420	1 535 080	2 080 634	2 432 978	.....
June.....	693 260	1 541 277	1 991 979	2 253 172	.....
July.....	624 900	1 461 375	1 846 829	2 005 719	.....
August.....	645 760	1 619 832	1 893 304	2 161 083	.....
September	710 220	1 744 089	2 056 473	2 357 733	.....
Total for year ending with September.....	7 955 200	14 964 330	23 268 432	27 377 930	.....
Total for year ending with February	9 234 690	19 964 600	25 316 248	28 752 004	

DIAGRAM SHOWING FLUCTUATION OF PASSENGER TRAFFIC, FROM DECEMBER 1, 1884, TO APRIL 15, 1888.

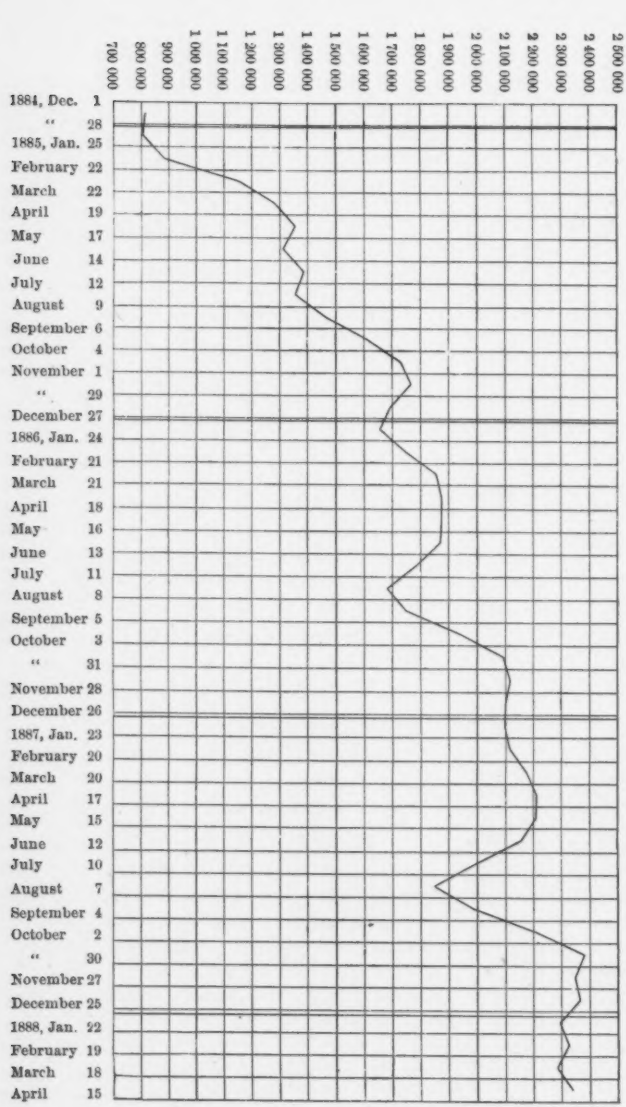

TABLE V.—PASSENGERS CARRIED CERTAIN DAYS AND PARTS OF DAYS.

Day.	From New York.				From Brooklyn				Total carried in 24 hours.	Train service.	
	Maximum in one hour.	Between 7 A.M. and 7 P.M.	Between 7 P.M. and 7 A.M.	In 24 hours.	Maximum in one hour.	Between 7 A.M. and 7 P.M.	Between 7 P.M. and 7 A.M.	In 24 hours.		Time that the trains ran.	Hours that the trains ran.
1883. Oct. 18..	1 420	5 950	1 270	7 220	1 560	7 840	1 440	9 280	16 500	6 A.M.–12 P.M.	18
1884. Feb. 27.	2 174	7 070	2 090	9 160	3 073	1 780	2 060	13 840	23 000	6 A.M.– 1 A.M.	19
Mar. 25.	2 325	8 990	2 290	11 280	2 765	11 740	2 220	13 960	25 240	" "	"
April 28.	2 405	9 180	2 440	11 620	3 090	12 220	2 260	14 480	26 100	5 A.M.– 1 A.M.	20
May 20.	2 503	8 930	2 210	11 140	3 006	11 710	2 450	14 160	25 300	" "	"
June 25.	2 480	8 060	1 820	9 880	3 950	9 690	2 670	12 360	22 240	" "	"
July 17.	2 150	7 430	1 910	9 340	2 570	9 840	2 140	11 980	21 320	" "	"
Aug. 13.	2 085	7 990	1 970	9 960	2 496	9 960	2 400	12 360	22 320	" "	"
Sept. 17.	2 512	9 060	2 130	11 190	3 035	11 587	2 300	13 887	25 077	" "	"
Oct. 11.	2 710	10 247	2 830	13 077	3 280	13 285	2 750	16 035	29 112	" "	"
Nov. 17.	2 980	10 515	2 175	12 690	3 709	13 854	2 250	16 104	28 794	" "	"
Dec. 20.	3 480	10 683	2 845	13 528	4 620	16 211	2 195	18 406	31 934	12 P.M.–12. P.M.	24
1885. Feb. 24.	3 473	12 608	3 220	15 828	4 725	17 883	2 800	20 683	36 511	" "	"
1886. May 25.	7 187	25 306	6 840	32 146	7 870	30 807	7 284	38 091	70 237	" "	"
1887. Nov. 29.	9 402	33 516	9 200	42 716	10 068	40 721	7 693	48 414	91 130	" "	"
Mean per cents. in 24 hours.	22.3	79.5	20.5	100.	21.8	83.6	16.4	100.		Carried one way.	
	10.	35.5	9.1	44.6	12.1	46.3	9.1	55.4	100.	Carried both ways.	

19th.—Power Expended.—Observations from time to time have been made, to determine the power expended in hauling the cable. For two days in November, 1883, during the afternoon hour when the travel was the greatest, indicator cards were taken from the driving engine at short intervals; at the same time the movement of the trains and the number of passengers each carried were noted, and from the data thus obtained, the two diagrams, Plates XXIX and XXX were prepared. In these, the paths of the trains are shown by the broken lines, the engine horse-powers by the irregular full lines, and the times the cards were taken by the small circles. The profile underneath each diagram serves to locate the trains at any particular moment of their passage over the Railway. During the entire working day, 19½ hours, April 26, 1886, also before and after the trains were put on

TABLE VI.—PASSENGERS CARRIED EACH HOUR OF THE DAY.

Hour beginning at	Tuesday, May 25, 1886.			Tuesday, November 29, 1887.		
	From New York.	From Brooklyn.	Totals.	From New York.	From Brooklyn.	Totals.
12 P M.	320	155	475	389	197	586
1 A.M.	195	104	299	249	62	311
2 "	158	131	289	211	80	291
3 "	93	129	222	111	128	239
4 "	112	144	256	112	139	251
5 "	127	432	559	143	370	513
6 "	410	2 708	3 118	469	2 894	3 363
7 "	505	7 870	8 375	841	9 366	10 207
8 "	645	7 483	8 128	712	10 068	10 780
9 "	746	3 489	4 235	1 007	4 589	5 596
10 "	799	1 834	2 633	1 144	2 776	3 920
11 "	968	1 450	2 418	1 333	2 267	3 600
12 M.	1 033	1 275	2 308	1 345	1 618	2 963
1 P.M.	1 012	1 480	2 492	1 416	1 969	3 385
2 "	1 361	1 601	2 962	1 620	1 687	3 307
3 "	1 662	1 227	2 889	2 109	1 897	4 006
4 "	2 294	1 061	3 355	4 068	1 843	5 911
5 "	7 094	1 113	8 207	9 402	1 580	10 982
6 "	7 187	924	8 111	8 519	1 121	9 640
7 "	1 921	1 101	3 022	2 251	1 402	3 653
8 "	915	711	1 626	1 373	652	2 025
9 "	855	598	1 453	1 314	562	1 876
10 "	896	607	1 503	1 271	667	1 938
11 "	838	464	1 302	1 307	480	1 787
Total.....	32 146	38 091	70 237	42 716	48 414	91 130

and taken off, indicator cards were taken from the driving engine, at half and quarter hour intervals; the horse-powers so determined are shown by the diagram, Plate XXVIII; representative cards, and one recording nearly the maximum power developed by the driving engine at any time are reproduced in Plate XXVII. Referring to the diagram, it will be seen that the indicated power used on the day mentioned, ranged from 303.1 horse-power maximum to 12.9 horse-power minimum and

negative; that the mean for the whole 19½ hours the trains were hauled was 96.2 horse-power; that for 5 hours from 7-30 to 9 o'clock A.M. and from 4-30 to 7 o'clock P.M. it was 150.5 horse-power, and for the remaining 14½ hours it was 74.4 horse-power; also to drive the plant without trains, it was 47.7 horse-power.

The diagram exhibits great and abrupt fluctuations of power; in one instance an increase of 190 horse-power within fifteen minutes, and in another, 239 horse-power within thirty minutes. There are also large differences in the power indicated at the two ends of the steam cylinder; this is, however not due as may at first be inferred, to an ill adjustment of the steam valves, since at one time the greater power is developed at one end, and at another time, at the other end of the cylinder. These variations of power are not unusual in the working of the driving engines; a brief observation in the engine room, when the cable is hauled, will show that the power applied often varies much more abruptly, at shorter intervals and between wider limits than here recorded. In explanation of this it may be said, that although the engines are equipped with an automatic valve gear of approved design, the regulation, under the quick and large changes in load, is slow and late, and therefore frequently too great in one direction or the other; as seen by an inspection of the Railway profile, Plate XXVI, the Stations are not at the same elevation, the summit is not midway between them, and the inclines leading from them are not alike; and lastly, the trains are almost always unequally laden, and often at unequal distances apart.

The diagram shows that five times during the working day observed, ndicator card taken was negative; at these and other times within the intervals at which the observations were made, the steam was cut off, perhaps the throttle valve was closed by the engineer in charge, and the engine was driven by the back haul from the outgoing line of cable; the preponderance of load at such time being on the down grades and in excess of the friction of the cable driving plant. This racing frequently occurs; generally when the travel is comparatively light, or when to lengthen the headway, trains are being removed. Usually it continues but a brief period, during which, however, the speed of the engine is sometimes greatly increased; thus on one occasion 56 revolutions were made one minute, 84 revolutions the second minute and 56 revolutions the third minute; whence the normal speed, 57 revolutions per minute was, in the short interval, nearly doubled. There being more and longer trains run now than formerly, as may be expected, the engine races more frequently.

The engines described and in use since the Railway was first operated, have singly furnished power sufficient for the maximum service; except on rare occasions, as for instance, in unfavorable weather, when the trains, heavily laden and frequent, in consequence of an interference with headway, were most of them moving up grade; and as has oc-

curred a few times, when the brakes were not released as the train was leaving a Station, or by a leakage in the air pipes, were applied while the train was in motion ; then the driving engine has slackened speed considerably, and even came almost or quite to a dead stop. The greatest power indicated by a single engine at any time is 394.5 horse-power.

20th.—Traction of Trains.—Observations made June 1 and 2, 1887, to see how far a train moved from a state of rest in acquiring full cable speed, gave 106.6 feet or about two-thirds the train length, as the mean of 11 tests, with trains of 3 cars. To determine how much of the power developed by the driving engine is expended in hauling the trains and how much in overcoming the friction of the cable driving plant, cars have been drawn over the Railway by locomotives, with a dynamometer substituted for the connecting link; the results thus obtained were diverse and unsatisfactory, and they are not here quoted. The following examination is based upon data given in the preceding Article and embodied in the diagram, Plate XXVII. During the 19½ hours the engine ran, April 26, 1886, there were hauled each way, 501 trains and 1 072 cars, weighing 11 256 tons; these carried from New York about 32 000 passengers, weighing (at 16 passengers per ton) 2 000 tons, and from Brooklyn, about 35 000 passengers, weighing 2 188 tons. While attached to the cable, the trains from New York to Brooklyn were raised 26.2 feet and from Brooklyn to New York, lowered 24.8 feet; these being the differences in elevations of the points where the grips were applied at one Station and released near the other Station. Using this data, the computed mean traction of the trains during the working day is equivalent to 37.5 horse-power;* the mean power developed by

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* Placing G for the grade in feet per hundred or per cent., n for number of cars in the train, T for its weight in tons (of 2000 pounds) and V for its speed in miles per hour; the resistances, R in pounds, to be overcome in moving a train at uiform speed is expressed as follows: The axle or rolling friction may be taken at $5.4T$; the air pressure against the head of the train, at $0.28V^2$ and against the sides of the cars at $0.003nV^2$; the resistance due to oscillation and percussion at $0.006TV^2$, and the resistance due to grade at $20GT$. Collecting these, and writing m as a multiplier of the co-efficients which may be subject to change ;

$$R = (5.6m \pm 20G)\,T + (0.28 + 0.03n + 0.006T)\,mV^2; \quad (a)$$

and for $V = 10$:

$$R = (6m \pm 20G)\,T + (3n + 28)m; \quad (b)$$

Comparing the results obtained by this formula with observations made on the traction of trains on the Railway, 1.3 was taken as a probable value of m; whence the equations become:

$$R = (7.2 \pm 20G)\,T + (0.36 + 0.04n + 0.008T)\,V^2; \quad (c)$$

and for $Ve = 10$:

$$R = (8 \pm 20G)\,T + 4n + 36, \quad (d)$$

In starting the train, the initial rolling friction for the first 100 feet, to be added to $7.2T$, is taken at 10 pounds per ton or $10T$; and in acquiring full speed, the resistance developed in the space the train thus moves (a function of the "velocity head" $\frac{V^2}{2g}$) becomes $68.85TV^2$.

the driving engine was 96.2 horse-power; or about one-eighth of the maximum power, taken as per indicator card, Plate XXVII, at 380.7 horse-power. It is assumed, in the absence of information to the contrary, that in addition to the friction of the plant itself, the loads impose an increase varying with them; placing E for the maximum power of driving engine, e for the power required to operate the plant without trains, R for the traction of trains and F for the coefficient of friction due to the latter; then $E = e + (1 + F)\,R$, and $F = \dfrac{E - e - R}{R}$. Substituting the numerical values given above, $F = 0.3$; whence the friction of the cable driving plant due to the traction of the trains was on the day mentioned, three-tenths of the load; and probably on other days does not vary greatly from this.

21st.—Hauling Power of the Drums.—The capacity of a cable driving plant, like that in operation on the Bridge Railway, is limited by the hauling power of the drums as well as by the motive power of the driving engine. In a few instances, similar to those referred to in the last paragraph of Article 20, when the engine was overloaded, the cable generally at the time being wet and dripping, it has slipped on the winding drums; if when this took place, the maximum power of the engine, say 380 horse-power was exerted—making due allowance for the friction of engine and drums—probably not more than 350 horse-power was transmitted to the incoming cable. This is equivalent to a direct haul of 13 125 pounds; the tension car causes a stress on each cable of about 1 785 pounds; whence the total resisting stress on the incoming cable would be greater than 14 910 pounds, of which the stress on the outgoing cable is less than 12 per cent.; this corresponds quite closely with the theoretical efficiency of a cable driven by one drum and wound as it is in this plant, the cable and grooves being not lubricated.* Since, however, when the cable has slipped on the drum (except in one instance), both were wet; without doubt, much less than the maximum power of the driving engine was then exerted.

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* The general problem in this case is: Given two drums, with a cable making one-fourth turn around the first drum, then in succession three or four half turns around each drum, and finally one-fourth turn around the second drum; required what tractive force may be exerted on the cable; the first and both drums being driven, and in each, with the cable and grooves fully lubricated, half lubricated and not lubricated. Placing for one groove, P_1 for the tension in the incoming and p_1 for that in the outgoing cable,

$$P_1 = p_1\, e^{\alpha f} \quad (e)$$

in which f is the coefficient of friction between the cable and groove, taken with full lubrication at 0.1, with half lubrication at 0.15, and with no lubrication at 0.2; α is the arc of contact of the cable and the particular groove with radius equal to unity, being therefore $\frac{\pi}{2}$ for one-fourth turn and π for one-half turn; and e is the base of the Naperian system of logarithms, whence $e^{\alpha f}$ is the number whose common logarithm is $\dfrac{\alpha f}{2.302585}$. From equation ($e$), remembering that the stress on the cable outgoing from one groove is that on the cable incoming to the next or following groove; Table A is computed, in which the total stress on

III.—WEAR, RENEWALS AND CHANGES.

22d.—Wear of Grooves in the Drums.—Soon after the Railway was first operated, (November 17, 1883) a counter, registering 100 000, was attached to the driving drum, and since a record of the revolutions daily made has been kept. From this, estimating the number of revolutions from the opening of the Railway to traffic (September 24, 1883) to the time the record began, at 1 275 250, and taking 12 feet as the mean diameter of the driving drum—whence each revolution equals 0.00714 miles, or 140 revolutions, one mile nearly—Table VII was compiled. Great pains were taken when the winding drums were made, to have the centers of the semicircular grooves for the cables of equal diameter and as nearly 12 feet as possible. The cylindrical face of each drum was carefully turned and the grooves fitted to a comb-shaped templet, which bearing against the face, entered each groove and gauged its depth. The accuracy of the work was tested by calliper-ing the drums at the bottoms of the grooves, and also by measuring their circumferences with a small revolving disk. The wear of the grooves was soon apparent, and from time to time was measured. February 2, 1884, the grooves of the driven drum were 0.02 inches less in diameter than those in the driving drum. The results of other measurements are given in Table VIII.

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the incoming cable, $P = 1$. The values here given of $P - p$ and p, for "First drum driven" and "Four grooves," correspond to the case of the present cable driving plant; equation (e),

TABLE A.—TRACTIVE POWER OF WINDING DRUMS.

Coefficient of friction, $= f$.	First Drum Driven.				Both Drums Driven.			
	Four grooves.		Five grooves.		Four grooves.		Five grooves.	
	Tractive power $= P - p$.	Stress on outgoing cable $= p$.	Tractive power $= P - p$.	Stress on outgoing cable $= p$.	Tractive power $= P - p$.	Stress on outgoing cable $= p$.	Tractive power $= P - p$.	Stress on outgoing cable. $= p$.
0.1	0.667	0.333	0.715	0.285	0.889	0.111	0.919	0.081
0.15	0.808	0.192	0.848	0.152	0.963	0.037	0.977	0.023
0.2	0.889	0.111	0.919	0.081	0.988	0.012	0.993	0.007

and the quantities deducted therefrom, given in the Table, however apply to a perfectly flexible cable of invariable length, whatever the stress to which it is subjected. In practice neither of these conditions obtain, and though probably the values stated of the tractive power and of the stress on the outgoing cable are nearly correct, the stresses on the intermediate lines between the drums must differ considerably from values therefor determined by the formula.

TABLE VII.—REVOLUTIONS OF DRIVING DRUM AND HAUL OF CABLE.

From	Revolutions of the driving Drum.					Miles the Cable was hauled.				
	1883–84	1884–85	1885–86	1886–87	1887–88	1883–84	1884–85	1885–86	1886–87	1887–88
Sept. 23 to Nov. 1.....	905 820	.....	.....	.....	.....	6 468	....	....	....	....
Oct. 30 to May 1	4 870 680	5 088 620	5 007 790	5 070 130	4 794 160	34 776	36 333	35 755	36 201	35 515.
April 30 to Nov. 1.....	5 274 350	5 217 340	5 156 010	5 150 390	.....	37 659	37 252	36 814	36 774	....
Totals to May 1, 1888.....	46 715 290					333 547				

TABLE VIII.—WEAR OF GROOVES IN THE DRUMS.

When measured.	Apr. 21, 1886.	Apr. 23, 1886.	May 5, 1887.	May 6, 1887.	Feb. 1, 1888.	Feb. 2, 1888.
Drum.	Driving	Driven	Driving	Driven	Driving	Driven
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Depth of first groove	0 24	0.16	0 33	0.27	0.41	0.38
second groove.....	0.26	0 21	0.37	0.34	0.43	0.39
third groove.....	0.23	0 2	0.38	0.34	0.41	0.39
fourth groove.....	0 22	0.21	0 35	0.33	0.35	0.38
Mean depths of the four grooves.....	0.2375	0.195	0 3375	0.32	0.4	0.385
Total number of miles the cable had been hauled when measurement was taken	186 422	186 831	262 261	262 463	316 310	316 511
Resulting mean diameter of drum, inches.....	143.525	143.61	143.285	143.36	143.2	143.23.
Comparative number of revolutions made to haul the same length of cable without slip*	1 690	1 689	1 912	1 911	4 774	4 773
Per cents.....	100	99.9408	100	99.9477	100	99.979
Total wear in cubic inches: for each drum when measurement was taken.....	638.32	524.25	960.03	859.55	1 074.18	1 033.67
for each drum per mile of cable hauled.....	0.003424	0.002806	0.00366	0.003275	0.003396	0.003266
for both drums when measurement was taken.....	1162.57		1 819.58		2107.85	
for both drums per mile of cable hauled.....	0.00623		0.006935		0.006662	

* For, this let D and d be the diameters, N and n the number of revolutions, of the driving and driven drums, respectively; then when the driven drum has lost one revolution;

$$N - 1 = n, \text{ and } DN = dn; \text{ whence } N = \frac{d}{d - D}.$$

It will seen that this wear was not uniform; the first cable when removed November 7, 1886, was reduced in diameter to $1\frac{3}{8}$ inches, and the grooves it had deepened were barely wide enough to receive the new cable, which for a time wore mainly on the sides and not on the bottom of the grooves. Up to February 1, 1888, the total wear of the grooves in both drums was $\frac{3}{4}$ cubic inches for each 100 miles the cable was hauled; that is, one cubic inch of solid cast-iron was cut from the grooves and ground to powder each 15 hours the plant was running.

23d.—Slip of the Drums.—If the cable did not increase in length under stress, the two drums would revolve inversely in proportion to their diameters; in practice, however, it is quite different: the driven drum lagging behind the other, in a ratio increasing with the loads imposed. A counter being attached to each drum, these results were obtained (Table IX), from which it appears that this slip in June, 1887, was nearly twice so great as in November, 1883; although probably, the drums were more nearly equal in diameter at the later than at the earlier date.

TABLE IX.—SLIP OF DRUMS.

Date of Observation.	November 18 to 21, 1883.		April 20 to 23, 1886.		June 22 to 24, 1887.	
Drum.	Driving.	Driven.	Driving.	Driven.	Driving.	Driven.
Revolutions in the same time	1 567	1 566	1 090	1 089	804	813
Per cents.....	100.	99 9361	100.	99 9083	100.	99 8756

24th.—Creeping of the Cable on the Drums.—A little consideration will show that necessarily, the cable must, as it passes from groove to groove around these winding drums, creep more or less in each groove; to this action the wear of the grooves and largely of the cable is due. If the incoming and outgoing lines were equally strained, or resisted stress without change in length, the cable could not creep unless the grooves in a drum were of unequal diameter. Rarely however, do either of these conditions obtain. The stresses on the two lines range; for the incoming cable from that caused by the maximum haul and the tension car together when the load is greatest and positive, to that caused by the tension car alone when the load is least and negative; and similarly for the outgoing cable from that caused by the tension car alone to that caused by it together with the negative load which sometimes exceeds 75 per cent. of the positive load. The cable extends or contracts in length as the loads imposed increase or diminish, and such changes corresponding in extent to the differences in stresses on the incoming and outgoing lines, must take place in the cable on the drums between the points where the

wrapping begins and ends. Hence, as the grooves in a drum revolve together, the cable in two of them will creep in one and in the other two in the contrary direction; the slip of the driven drum will be determined by the mean of these movements and the difference, if any, between the diameters of the two drums. The resulting wear will therefore be nearly alike for the grooves of either drum and somewhat the greater for those in the driving drum.

25th.—Breakage of Drums.—The drums were made each with flat double arms and two hubs which with the rim were in one piece, as shown in Plate V; in casting, the hubs were split radially into three parts; in finishing, wedges were driven into the spaces so formed and wrought iron bands shrunk on. It was first intended to drive both of the larger drums by means of the smaller friction drum in contact between them and keyed to the main shaft; it was thought that sufficient pressure to develop the necessary tangential friction would be induced by the tension on the several lines of wrapped cable, and if need be, this pressure was to be increased by forcing keys in between the pillow-blocks of the larger drums and the frame. Before, however, this part of the plant was finished, the pinion keyed to the main shaft and the gear wheel bolted to one or the driving drum, were added (see Plate II); and the friction drum was left free to revolve independently of the main shaft, between the two other drums and aid in driving the one without a gear wheel. As so arranged, the plant for a time was operated; soon, however, arms of the smaller and then of one of the larger drums, one after the other, cracked, each quite close to the rim and separated from it. January 25, 1884, several arms of the large drum, all of the arms on one side and most on the other side of the smaller drum, had so failed and been reinforced by segmental iron plates bolted to the broken parts and joining them together. Acting upon the suggestion that these breakages were mostly due to the deforming stresses which, as the drums revolved, constantly tended to diminish the horizontal and increase the vertical diameters; the larger drums were then wedged apart about $\frac{1}{8}$ inch, whereby the smaller drum was relieved from pressure and consequently from work; the winding drums ran more smoothly than before, the slip apparently did not increase and no other arms failed. Since the friction drum was thus relieved, the winding drums as repaired have been continuously operated and are still in use; the only stoppages being during the past year to renew one of the wrought iron hub bands on the driving drum twice, and one on the driven drum once; these were put on, in halves with bolts, without much delay.

26th.—The new Drums.—In preparation for a possible ultimate failure, duplicate drums were early provided, shown in Plate VI, and have since been kept in reserve. In these the arms are hollow and of an elliptical section; they and the hub on one side were cast in one piece, the rim in another, the bearing surfaces were finished, and the three

parts which collectively form a drum, were bolted together with finished bolts driven into reamed holes.

27th.—Wear of the Engines, Clutches and Gears.—Taking into consideration the irregular and constant work demanded of them, the driving engines have served well; the work has been quite equally divided between the two; as arranged but one can be operated at a time, and to change from one to the other, the plant must be stopped. The jaw clutches, shown in Plate III, whereby they are connected with the drums, have worn greatly. These are of the ordinary form, with two projections on each side; the outer diameter of the bearing surfaces is 26 inches and the mean inner diameter 16½ inches, the depth of jaw is 4 inches; whence the total area of bearing surfaces is 38 square inches; these have worn away about $1\frac{3}{16}$ inches, thus 45½ cubic inches of solid metal have been removed from each or 90¼ cubic inches from both clutches during the time they have been in use. The gear teeth are of the epicycloidal form; they were cut accurately to shape. The bearing surface of each tooth is 12 inches wide and 6.4 inches long, or 76.8 square inches; a recent careful examination failed to show perceptible wear.

28th. Description of the Cable.—The specification for the hauling cables used on the Bridge Railway requires, that each cable shall have 6 strands of 19 wires, laid up under a strain of not less than 10 000 pounds, in a regular right hand lay of medium length and around a core of the best hemp rope, well tarred; it shall be 1½ inches in diameter, weigh 3.1 pounds per foot in length,* and withstand a stress of 50 tons; the wires of which the cable is composed shall be of "steel of a uniform and suitable quality;" they shall be about $\frac{1}{16}$ inch in diameter and withstand a stress of 1 000 pounds each; specimens under tensile strain shall, if 12 inches long, stretch not less than 4 per cent., and if 60 inches long, not less than 3½ per cent; they shall also be capable of being wound around a rod ¼ inch in diameter and straightened again without fracture; the ends of abutting wires shall be joined well together with brass solder, and no strands shall be spliced.

Upon examination it is found: the diameter of the cable being 1½ inches, that of each strand is ½ inch, and consequently of the center of the strands is 1 inch; the strands are so laid that they make one revolution around the cable in 8¾ inches, and the wires similarly around a strand in 3 inches, each of cable length. Therefore the ratio of the length of the cable to the length of a strand and of its central wire is 1.0624; to the 6 inner wires of a strand is 1.0855, and to the 12 outer wires is 1.1984; the mean of these ratios for a single wire is 1.1556.†

* The first cable, as made and delivered, weighed 3¼ pounds per foot in length.

† In computation, the extension within elastic limits of one of these cables, under tensile strain, has been taken empirically for the whole cable at 0.000 000 07 per pound of stress per foot in length.

29th.—STRENGTH OF THE CABLE.—The record is not at hand of tests of wires for the first cable which was worn out, and for the second cable which is now in use; that of tests of wires for the third and fourth cables, now in reserve, is given in Table X. The specimens were taken from coils selected at random from the stock prepared, three being cut from each coil so selected; two of these were subjected to tensile strain and the third was wound around a rod $\frac{1}{4}$ inch in diameter. The last test in each case was satisfactory, the specimen being coiled several turns and then straightened; it was also bent back and forth many times without fracture.

TABLE X.—TESTS OF STEEL WIRE UNDER TENSILE STRAIN.

Cable and date.	Number given, to coil of wire tested.	Diameter of wire, inches.	Length of specimen, inches.	Breaking strain.		Elongation. Per cent. of length.	Length of specimen, inches.	Breaking strain.		Elongation. Per cent of length.
				Per specimen, pounds.	Per square inch, pounds.			Per specimen, pounds.	Per square inch, pounds.	
Third cable, January 4, 1887.	1	0.095	60	1 390	193 400	4.8	12	1 220	169 700	7.
	2	"	"	1 210	168 300	5.8	"	1 403	195 900	5.
	3	"	"	1 230	171 100	3.2	"	1 236	172 000	7.3
	4	"	"	1 070	148 900	...	"	1 128	156 900	9.
	5	"	"	1 160	161 400	5.	"	1 214	168 900	8.
	6	"	"	1 086	151 100	4.1	"	1 132	157 500	9.
	7	"	"	....	.....	...	"	1 040	144 700	10.
	7	"	"	1 112	154 700	5.	"	1 160	161 400	8.
Fourth cable, September 14, 1887.	1	0.095	61	1 084	152 900	4.5	12	1 012	142 800	6.3
	2	0.099	"	1 114	144 700	6.7	"	1 134	147 300	7.1
	3	0.101	"	1 152	143 800	6.1	"	1 140	142 300	5.
	4	0.098	"	1 020	135 200	5.3	"	984	130 500	6.1
	5	0.101	"	1 210	151 000	4.9	"	1 280	159 800	7.5

To determine the loss in strength of the first cable, after it was removed, three pieces 23 feet long were put under tensile strain; they resisted up to 69 240, 68 060 and 68 049 pounds respectively, and the two last named stretched about $3\frac{1}{2}$ per cent.

30th.—Stretch of Cables.—During the period a hauling cable is used, it permanently stretches, at first rapidly and afterwards at a lesser rate and quite uniformly. Since March, 1883, a daily record has been kept of the position of the Brooklyn tension car. From this and earlier data, the stretch of these cables is readily deduced, and is here given.

TABLE XI.—STRETCH OF CABLES.

Cable.	Length of cable hauled, miles.	Stretch.				Cable.	Length of cable hauled, miles.	Stretch.			
		For total length hauled, feet.	For last 25 000 miles hauled, feet.	Per mile				For total length hauled, feet.	For last 25 000 miles hauled, feet.	Per mile	
				of total length hauled, inches.	of last 25 000 miles hauled, inches.					of total length hau'ed, inches.	of last 25 000 miles hauled, inches.
First.....	25 000	67.	67.	0.032	0.032	First.....	225 000	263.5	23.3	0.014	0.011
"	50 000	109.	42.	0.026	0.02	"	226 283	267.8	....	0.014	....
"	75 000	127.3	18.3	0.02	0.009						
"	100 000	150.6	23.3	0.018	0.011	Second...	25 000	136.	136.	0.065	0.065
"	125 000	176.5	25.9	0.017	0.013	" ...	50 000	172.	36.	0.041	0.018
"	150 000	192.5	16.	0.015	0.007	" ...	75 000	210.7	38.7	0 034	0.018
"	175 000	216.7	24.2	0.015	0.012	" ...	100 000	250.7	40.	0.03	0.019
"	200 000	240.2	23.5	0.014	0.011	" ...	107 274	287.	....	0.032	....

When taut and the tension car is at its highest position, the cable is about 11 400 feet long; whence the first cable during its entire use stretched 2.35 per cent., and the second cable, up to May, 1888, stretched 2.52 per cent. During each 8 hours of the first 40, after the second cable was put in, it stretched $16\frac{1}{2}$, $3\frac{3}{5}$, $6\frac{1}{4}$, $2\frac{1}{2}$ and $1\frac{3}{5}$ feet respectively, or altogether $30\frac{3}{5}$ feet; some of this doubtless was slack, not all taken out when the splicing was done. The stretch of a cable is due partly to the tension to which it is subjected, but doubtless much more to the action of the grips. As indicating the probable effect of their pressure on it, (see Article 37); referring to Table I, the grips were applied 1 074 times for the 329 trains run April 29, 1884; 2 150 times for the 515 trains run April 27, 1886; and 2 688 times for the 487 trains run May 1, 1888. Taking, (Article 20), 107 feet as the mean length of cable which passes be-

tween the grip sheaves, from the time the grip is closed until the train moves at full speed; on the days mentioned, the total length of cable thus subjected to pressure, was 114 918 feet, 230 050 feet and 287 616 feet; and if the compressed spaces were uniformly distributed, the whole cable passed between the grip sheaves, 10, 20 and 25 times respectively. As the cable stretches, the hempen core becomes harder, more compact and of course, smaller; from this, as well as wear, the cable also is reduced in size; the first, when taken out, being but 1¼ inches, and the one in use now is about $1\frac{5}{16}$ inches in diameter. Besides stretching permanently, the cable under changes of load and variations in temperature, extends or contracts within elastic limits, sometimes to a noticeable extent; data however, are lacking to determine with precision how much is this movement, separate from the other.

31st.—Renewing the Cable; Splicing.—The first cable was in continuous use from the opening of the Railway, to November 7, 1886; then it was replaced by the second cable, which is still serviceable. When a cable is put in place, its ends are spliced; it is respliced when the length of slack allows the Brooklyn tension car to reach its lowest position and then the cable is shortened; also when the wires at the splice are much worn, or many of them are broken, the defective part is cut out and a piece of new cable, of diameter the same as that of the worn cable, is inserted; in which case, two splices are necessary. During its use, the first cable was respliced seven times, twice with a single splice and five times with two splices; the second cable has been respliced four times, thrice with a single splice and once with two splices. The length of these splices varied; that of the second splice in the first cable was 96 feet, and that of those lately made is 60 feet; the shorter splice is found to be as serviceable as the others, and when resplicing is to be done, it is more likely to permit the old splice to be cut out. If a splice, say 60 feet long, were separated without disturbing the lay of the strands, leaving the lapped ends of the cable, side by side, as they were in the splice; it would be seen that for either cable end, the strand ends were one-sixth a splice length or 10 feet apart, except at the centre where they would be one-third a splice length or 20 feet apart; also—designating the cable ends by *A* and *B;* that the strands of *A* lapped by the corresponding strands of *B*, in pairs, each 2 feet. In making a splice, taking the strands in numerical order from the longest to the shortest, the first strand of *A* is wound into the place left by the shortened end of the sixth strand of *B;* the second strand of *A* into that of the fifth strand of *B;* and similarly for the other pairs of strands. Where the pair of strands, which are in one line, lap by each other; the cable is untwisted, 2 feet of the hempen central strand is cut out, and in place of the piece so removed, the free strand ends are tucked in. Thus the diameter of the cable at the splice is the same as elsewhere; except at the six points where the strand ends cross each other and are turned into

the central space; here the diameter is slightly increased. The cable to be spliced being on the sheaves and pulleys, hauled taut, and made fast, with the ends lapping by each other and left free, the splicing is done as follows: the strands at each end are unwound back to the centre of the splice; the two ends are brought closely together and wrapped, with the unwound strands of *A* interposed regularly between the unwound strands of *B;* then the sixth strand of *A* is cut close to the wrapping, unwound, and into the spiral space so left, the first strand of *B* is at the same time wound; not more than a single turn being permitted between the two strands; similarly the other strands are wound in. As the replaced strand sinks into the spiral space, it is seated by gentle blows from a copper hammer; and to untwist the cable, in tucking in the free ends of the strands, it is held in a strong, round jawed vise. Before splicing, the slack is taken out and the cable made taut by a tackle, to which a locomotive is attached. A foreman with a gang of eight men, will now make one of these splices, after the cable is in position and secured, in from two to three hours. The whole operation is usually done in the interval between the regular stopping of the cable, at 1 o'clock A.M., and starting it again at 5 o'clock A.M.

32d.—Wear of Cables.—By the constant bending of the cable around the sheaves and drums, where there must be a slight movement of the strands and wires over each other and particularly at the splices where the ends of the strands lap by, the inner projecting surfaces in contact are abraded and wires from time to time broken. Also somewhat by the action of the grip sheaves, but more by contact with the grooves in the sheaves and by the slip in the grooves of the drums, the outer surface of the exterior wires are worn away. An experimental grip, with revolving, solid metal jaws, was tried on one car, for a few trips, early in 1884; shortly afterward wires were found nearly or quite pinched off, being imbedded where they crossed as if sunken under a heavy hammer, and in one instance, 200 broken wires in 100 feet of cable length were reported. In a hauling cable however, the wires are constantly breaking; so long as the ends do not project and strip, the only injury which results, is the decrease in cable strength, and this is slight, if the breakages are evenly distributed and not close together. As may be expected, the wear requiring attention and repair is confined to the splice and its immediate vicinity; this repair, (Article 31), is usually done by inserting a new piece of cable; sometimes however, a short piece of badly worn strand has been replaced by a new one. No cable has been broken, and but once has a strand hauled loose and unwound. The loose end, which was drawn out at the splice, was first noticed near the Brooklyn outgoing sheave, and before the driving engine was stopped, it had passed through New York Station, and about 25 feet were unwound, however without injury to the pulleys and sheaves over which it had gone.

33d.—Cable Service.—The first cable was in use 3 years and 43 days, and the second cable, to May 1, 1888, has been in use 1 year and 176 days. The comparative service rendered by the two cables is shown by Table XII, in which certain items are estimated. By this it will be seen, that as a mean of the work done, over each mile it was hauled, the first cable moved 96.2 tons, and the second cable moved 200.8 tons.

TABLE XII.—CABLE SERVICE.

Cable.	Loads hauled.	Weights.	Total weights hauled.	Distance hauled.	Total service.
First cable, used 3.12—years, hauled 226 273 miles.	257 052 cars.	8½ tons.	2 184 992 tons.	.....	.....
	408 265 "	10 "	4 082 650 "	.....	.....
	172 578 "	16 "	2 761 248 "	.....	.....
	837 895 cars.	.....	9 028 890 tons.	$2\frac{1}{16}$ miles.	18 622 086 ton-miles.
	48 960 000 passengers.	125 pounds.	3 060 000 "	$1\frac{1}{32}$ "	3 155 625 "
	Total service.....	.....	12 088 890 tons	.....	21 777 711 ton-miles.
Second cable, in use 1.48 yrs., hauled 107 274 miles.	15 398 cars.	8½ tons.	130 883 tons.	.....	.....
	135 911 "	10 "	1 359 110 "	.....	.....
	476 823 "	16 "	7 629 168 "	.....	.....
	628 132 cars.	.....	9 119 161 tons.	$2\frac{1}{16}$ miles.	18 808 270 ton-miles.
	42 420 000 "	125 pounds.	2 651 250 "	$1\frac{1}{32}$ "	2 734 100 "
	Total service.....	.....	11 770 411 tons	.....	21 542 370 ton-miles.

34th.—Tension Car Renewals.—New wheels and axles were put under the Brooklyn tension car, February 21, 1886, in place of the first ones which were much worn; about this time the weight carried by the car was reduced 5 000 pounds, and a nearly equivalent direct weight of 1 100 pounds was attached by a wire rope and pulleys. The New York tension car at first had a single horizontal guide wheel, which ran loose on the sheave pintal and traversed the horizontal track described in Article 8. This failed and July 20, 1886, a pair of guide wheels smaller than the first and having independent journals were substituted; a new horizontal track was then also supplied; these are still in good condition. The sheaves of both cars have also been renewed.

35th.—Wear and Renewal of Sheaves and Pulleys.—Several of the sheaves first put in, made as shown in Plate X, failed by the wedges

driven in the split hub working out and the hub becoming loose on the shaft. Some of these were refitted, greater care being taken in wedging and banding the hub, and have served well since. Others were taken out because of wear in the grooves, and a part were replaced by sheaves made as shown in Plate XI. The wear in the grooves of those now in use was measured May 20, 1888. Table XIII records the renewal and wear of sheaves, arranged in order as the cable moves, beginning at the drums The first Brooklyn tension car sheave became loose in the hub; an arm of the second one, a sheave which had been repaired and was of the same design as the first, cracked near the shaft. Two sheaves have not been renewed; both have been repaired at the hub; the horizontal sheave in New York Station has been repaired twice and is now much worn in the groove as stated in the Table, and in the bore; its pinta; has been revolved so as to bring a fresh surface into bearing, and also is much worn. It will be seen that the New York outgoing sheave deflects the cable the least: and that excepting the two New York incoming sheaves, around six of the others about one-fourth turn and around the Brooklyn tension car sheave one-half turn is made. Around each of the first New York incoming sheaves about one-fourth turn was made as shown in Plate XVII; to increase the tractive power of the new auxiliary cable plant, around these sheaves now in use three-fourths turn was made, as shown in Plate XIX, and retained until a few months ago, when to permit a change in the switching arrangements, the cable was shifted to its former position.

Taking the wear of the grooves and the time such occurred, given in Table XIII as a basis, the estimated mean wear during the entire operation of the plant, is as follows: one cubic inch of cast iron was cut from the eight sheaves not packed, in 12½ hours; one cubic inch of wood from the two sheaves so packed, in 16¾ hours and one cubic inch of leather and india rubber from the two sheaves so packed in 43⅛ hours; and summing the two (see Article 22), one cubic inch of cast iron was cut from the grooves of the drums and sheaves together in 6¾ hours. The angles of contact between the several sheaves and the cable being considered; it is also estimated that under like conditions, the relative wear of the three styles of grooves will be about as follows: taking a groove packed with leather and india rubber as 10, that of one packed with wood will be 69, and of one not packed will be 25. This attrition is done by the cable, which must also be worn much more by the grooves that are not packed than by the others.

In renewing the sheaves, the diameter of the journals of two was increased from 5 to 6 inches, and of two others from 3 to 4 inches; wherever the pillow blocks were also renewed, those shown in Plate XIV were substituted for those first used, shown in Plate XIII. Before this was done, these journals frequently heated; they have given little trouble since the changes were made.

TABLE XIII.—RENEWAL AND WEAR OF SHEAVES.

Location of sheave.	Description.	Packing in groove.	Length and diameter of journals, inches.	When sheave was renewed.	Length of service, years.	Wear of groove.	
						Depth worn in groove, inches.	Length of wear, years.
Engine room, low frame....	Plate X.	None.	6 x 4	.....	....	....	....
	Plate X., repaired.	"	"	In use.	....	0.22	....
Engine room, tension car..	Plate X.	"	6 x 3	1885, May 24.	1.67	....	....
	Plate X., repaired.	"	"	1886, April 24.	0.92	....	....
	Plate X., repaired.	"	"	In use.	2.02	0.31	2.07
Engine room, high frame..	Plate X.	"	"	"	4.61	0.34	4.66
Brooklyn—outgoing.....	Plate X.	"	"	1884, June 15.	0.73	....	....
	Plate XI.	"	6 x 4	In use.	3.88	0.28	3.93
New York—first incoming	Plates X, XVII.	Wood.	6 x 5	1885, June 13.	1.73	0.84	1.73
	Plates XII, XIX.	Leather and rubber.	6 x 6	In use.	2.88	0 44	2.93
New York—second incoming	Plates X, XVII.	Wood.	6 x 5	1885, June 13.	1 73	0.5	1.73
	Plates XII, XIX.	Leather and rubber.	6 x 6	In use.	2.88	0.44	2.93
New York—horizontal....	Plate X.	None.	4-in. pintal.	"	4.61	0.53	4.66
New York—tension car..	Plate X.	"	"	1886, June 20.	2.74	....	....
	Plate XI.	"	"	In use.	1.87	0.38	1.92
New York—outgoing.....	Plate X.	"	6 x 3	1884, Dec. 8.	1.2	....	....
	Plate XI.	"	6 x 4	In use.	3.41	0.31	3.46
Brooklyn—incoming	Plate X.	"	"	1884, June 5.	0.7	....	....
	Plate XI.	"	"	In use.	3.91	1.03	3.96

The pulleys which support the cable between the rails, only have been renewed when the flanges or arms were accidentally broken, which however, has rarely happened; their packings wear quite regularly, the mean service being about ten weeks. A supply of repacked pulleys is kept in stock, and a change is quickly made, by a single workman, whenever necessary and while the cable is running. It was found that the tilting pulley shown in Plate XVI, by the inertia of its weight and other parts to be overcome when it is moved and as each car passes over it, gave quite a blow to the grip frame and tended to force it out of place; the coiled spring recently substituted for the weight (as described, Article 10), attached to the tilting lever so as nearly to balance it and the other parts during the entire movement up and down, has much reduced the concussion; the grip is kept with less care in its position under the car body, and the system of tilting pulleys at a platform is operated with greater ease and certainty.

36th.—Train Equipment.—As heretofore stated, the Railway was first supplied with cars, one-half 36 feet 4 inches long, weighing 8½ tons, and one-half 48 feet long, weighing 10 tons; the shorter cars were sold and others purchased 48 feet 10 inches long, weighing 16⅔ tons. It was soon found inconvenient to make up trains with cars varying much in length; for sufficient capacity the longer cars were required; and that they might endure the continuous service performed, without change in shape or frequent repairs, greater strength and consequently increased weight were requisite; to permit more rapid entrance and egress of the passenger load, side doors were added, and to control more certainly the train in any emergency on the steep grades of the railway, the vacuum brake which was first held in reserve, was fitted for constant use, thereby replacing the hand brake. To increase the effective brake resistance, some cars have been equipped with boxes from which sand may be discharged on the rails; so far, the necessity of such has not been proven. A large part, compared with other railways, of the round trip being over curves of short radii, frogs and switch points; the wheel flanges wear rapidly, and care has to be taken to preserve the gauge.

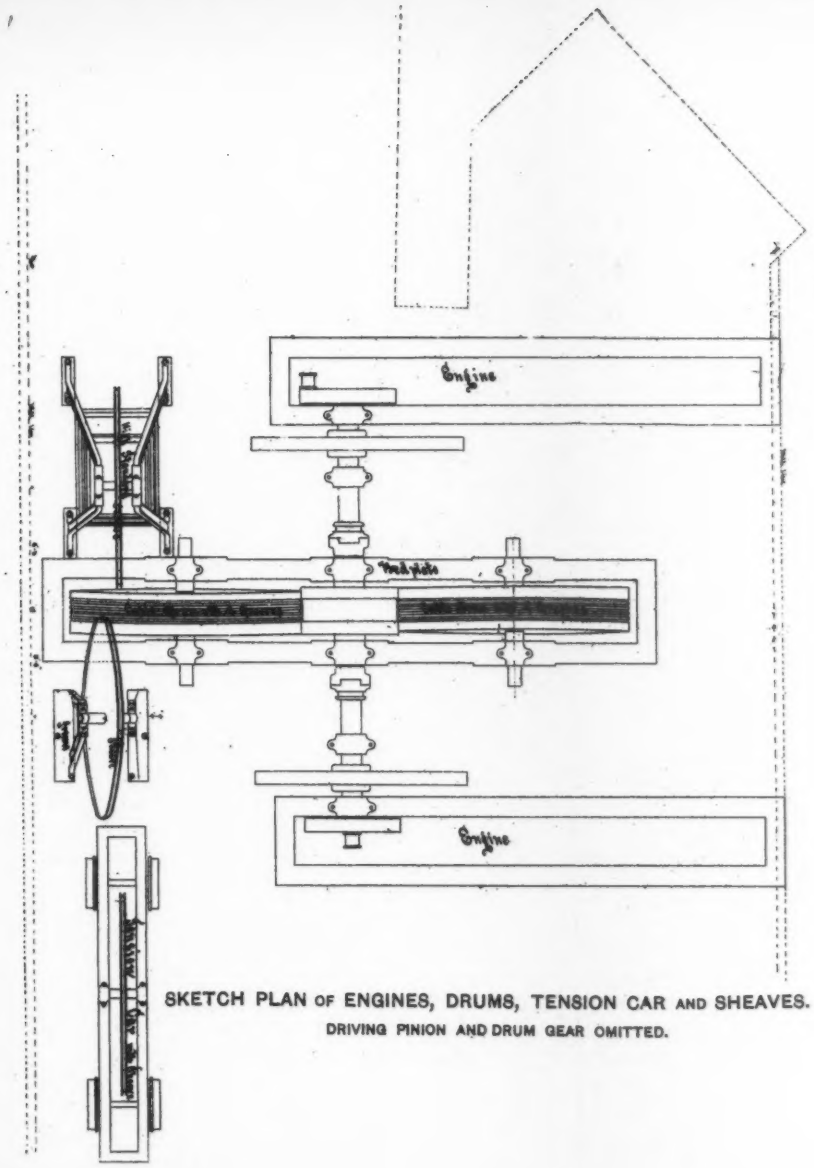
37th.—Grip Service.—By inserting a spring balance in the two lines of wire rope whereby the grip is operated (see Plate XXIV) it was found that the brakeman or gripman could apply over 400 pounds stress at the end of each grip lever. The friction of the sheave against the cable must always be greater than that of the brake against the inner periphery of the sheave, if the same pressure is applied to each, as in this grip; otherwise the cable would slip between the sheaves. The friction of oak against cast iron, both being dry and not lubricated, may be 25 per cent. of the pressure causing it; whence the tractive capacity of the grip will be equal to the pressure applied to each brake and to one-half that exerted by the grip lever. The multiplication by the grip gear

(Plate XXII) is 7.4 and by the grip lever when the grip is closed is 25; hence for 4 000 pounds direct haul, the pressure on each pair of brakes will be 8 000 pounds, and the stress at the outer end of each grip lever, 320 pounds; quite within the limit of working force the gripman may apply at the hand wheel; and much less than is usually exerted. As practically illustrating the power of the grip now used, this record is copied. On the evening of April 18, 1887, the driving engine was nearly stopped in consequence of an omission in the New York Station to uncouple from a three-car train attached to the cable by two grips, the switching locomotive, to the rear of which was coupled another three-car train; whereby the two grips were hauling six cars and a locomotive.

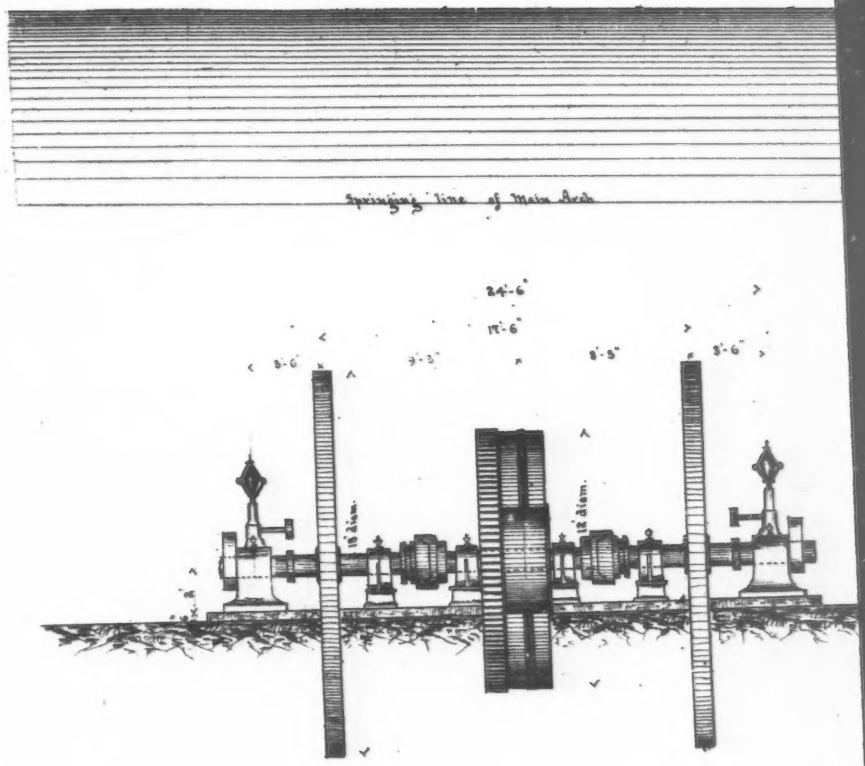
Aside from renewal of the sheave packings, the repairs to the grips are chiefly due to the train when entering a Station, running beyond the incoming sheaves without the cable being released, which sometimes happens. Thus in May, 1885, the forward grip was not opened as the train approached New York Station, and the cable was pulled out, bending the two lower side sheave shafts and slightly tearing the packings; the grip was used on the return to Brooklyn; the damaged shafts with their sheaves were replaced in a few minutes by others, and the car was again put in service. The accident was caused by the brakeman not being able to disengage the grip; probably after it was closed, as the train left Brooklyn Station, the cable splice drew in between the sheaves and strained the grip gear. The sheave packings of the grip first used, rarely served longer than 30 days, without renewal; the grip now used was first put on the Railway, April 2, 1885, and the cars were equipped with it in due course; a record of the service of all sheave packings of these grips is kept; from which it appears that from April 13, 1885, to March 31, 1888, 236 sets were inserted and removed; the term of service ranged from 348 to 37 days, and the round trips made from 9 815 to 962, the average being 4 075 round trips; taking $2\frac{1}{16}$ miles as the length of a round trip, the mileage ranged from 20 244 to 1 984; the average being 8 405 miles.

38th.—Lubrication.—At first, all bearings were lubricated with oil, from an oil can or cup; afterwards for most, was substituted a grease of the consistency of lard and flowing when slightly heated; with this a special cup is employed, having a screw cover which the attendant turns a little at proper intervals, in some cases only once a day, and forces the lubricant between the wearing surfaces. Generally, the grease is thus more conveniently applied than the oil; and so far as known in the absence of definite test, at considerably less cost. The first cable, before it was much worn, was coated with a hot mixture of vegetable tar and linseed oil; the second cable soon after it was put in was brushed with linseed oil; and in either case no other applications were made. How far such are economical is uncertain; a new cable, as delivered, is

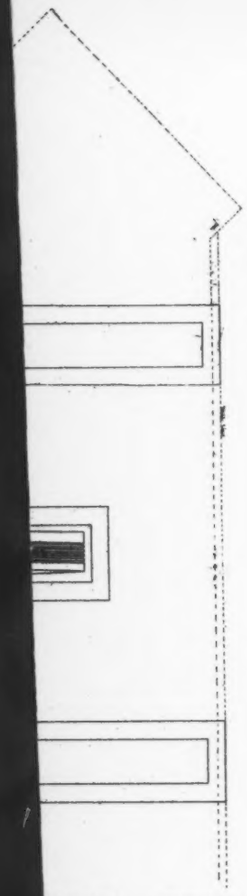
coated with tar, which prevents rusting while it is on the reel and held in reserve; when in use it externally is kept bright by the drums, sheaves and grips, and internally there is no oxidation. Could the wires forming the cable, where they overlap each other and are in contact, be lubricated, some wear at these places might be saved; but the cable is not likely to fail from this wear; any suitable coating will lessen the hold of the grip and the haul of the drums; a corresponding increase of grip pressure will be necessary, thus inducing a much greater destruction of the cable than that sought to be prevented, as well as adding to the wear of the packings of the grip sheaves.



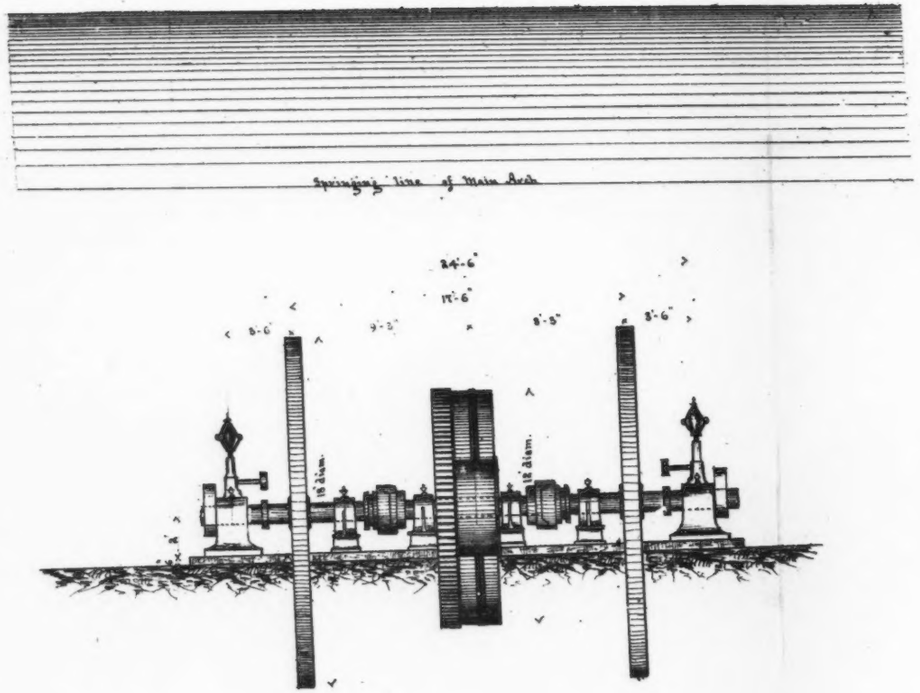
SKETCH PLAN OF ENGINES, DRUMS, TENSION CAR AND SHEAVES.
DRIVING PINION AND DRUM GEAR OMITTED.



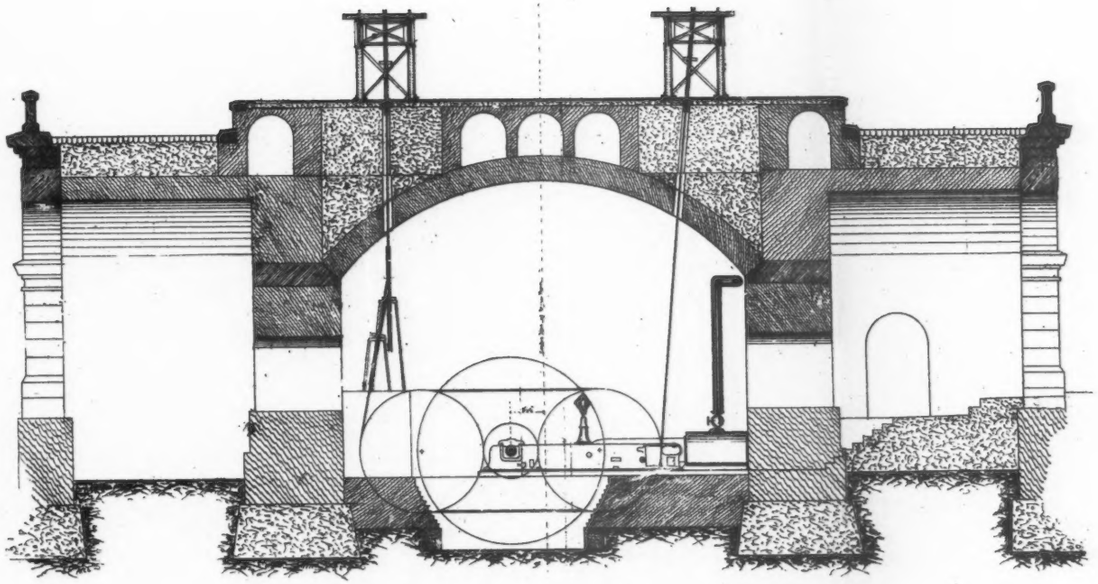
SKETCH ELEVATION OF ENGINES AND DRUMS.



ION CAR AND SHEAVES.
OMITTED.



SKETCH ELEVATION OF ENGINES AND DRUMS.



CROSS SECTION OF APPROACH.
SHOWING POSITION OF ENGINES AND DRUMS.

PLATE IV.
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VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

DRUMS, TENSION CAR AND SHEAVES.

DRIVING PINION AND DRUM GEAR OMITTED.

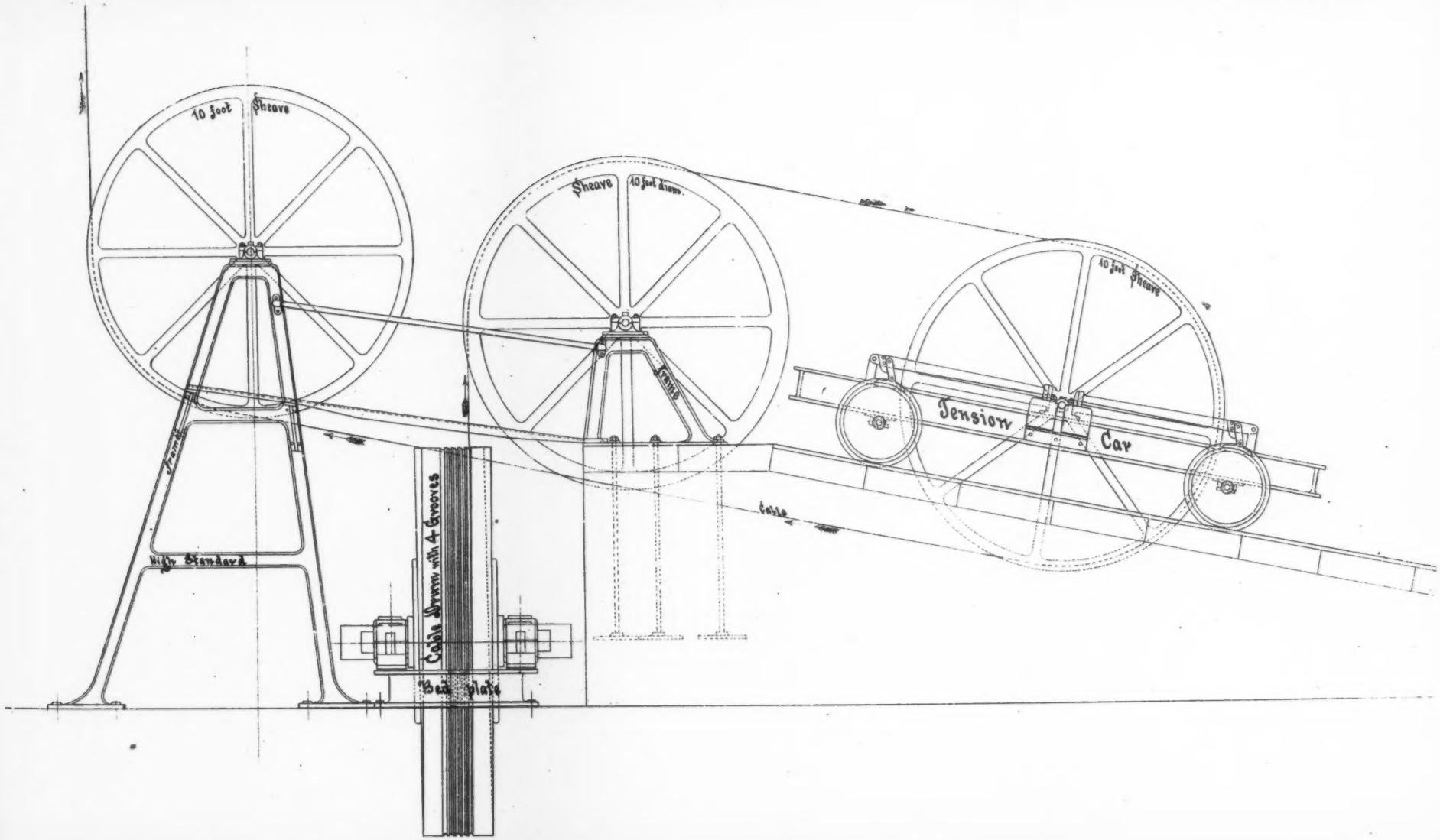
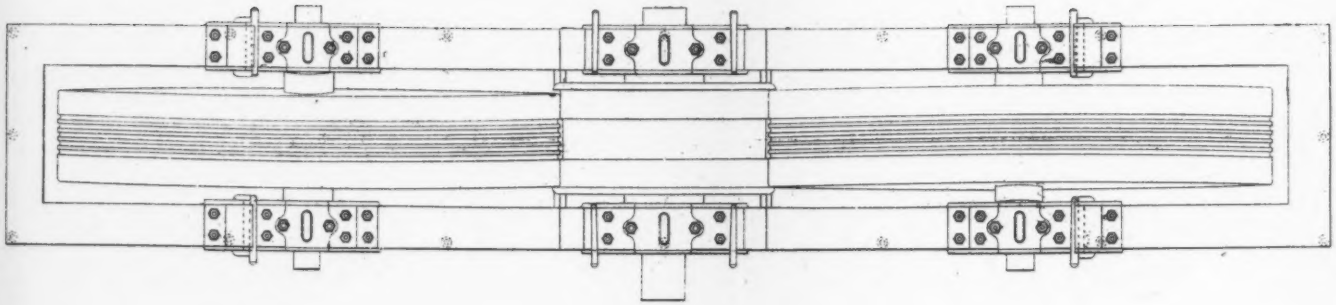


PLATE V
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

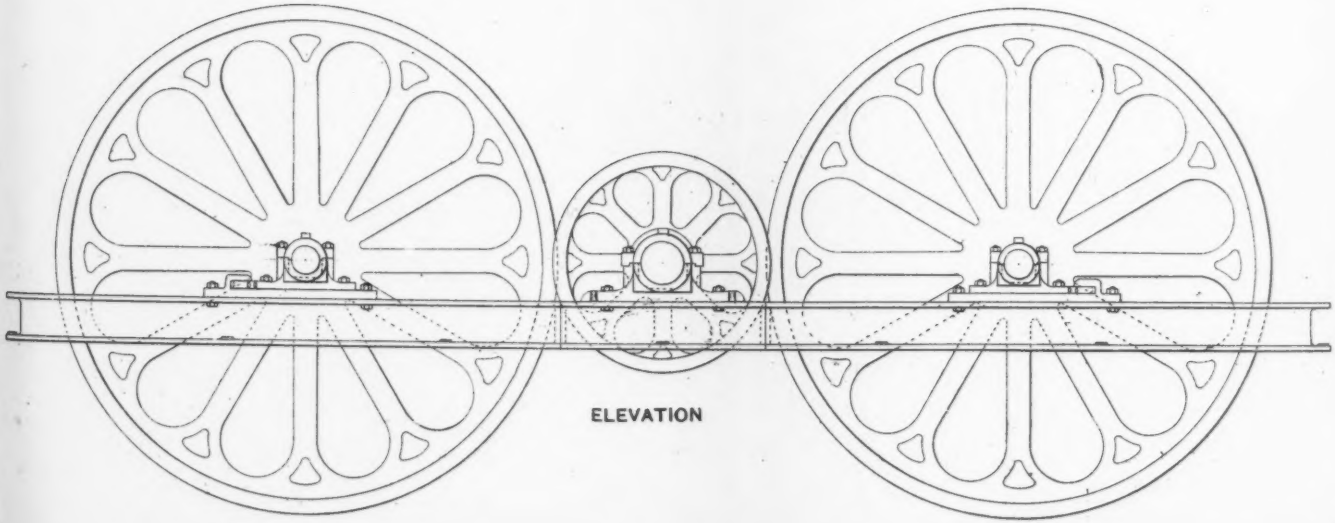
DRUMS AND FRAME.

AS FIRST MADE.

DRIVING PINION AND DRUM GEAR OMITTED.



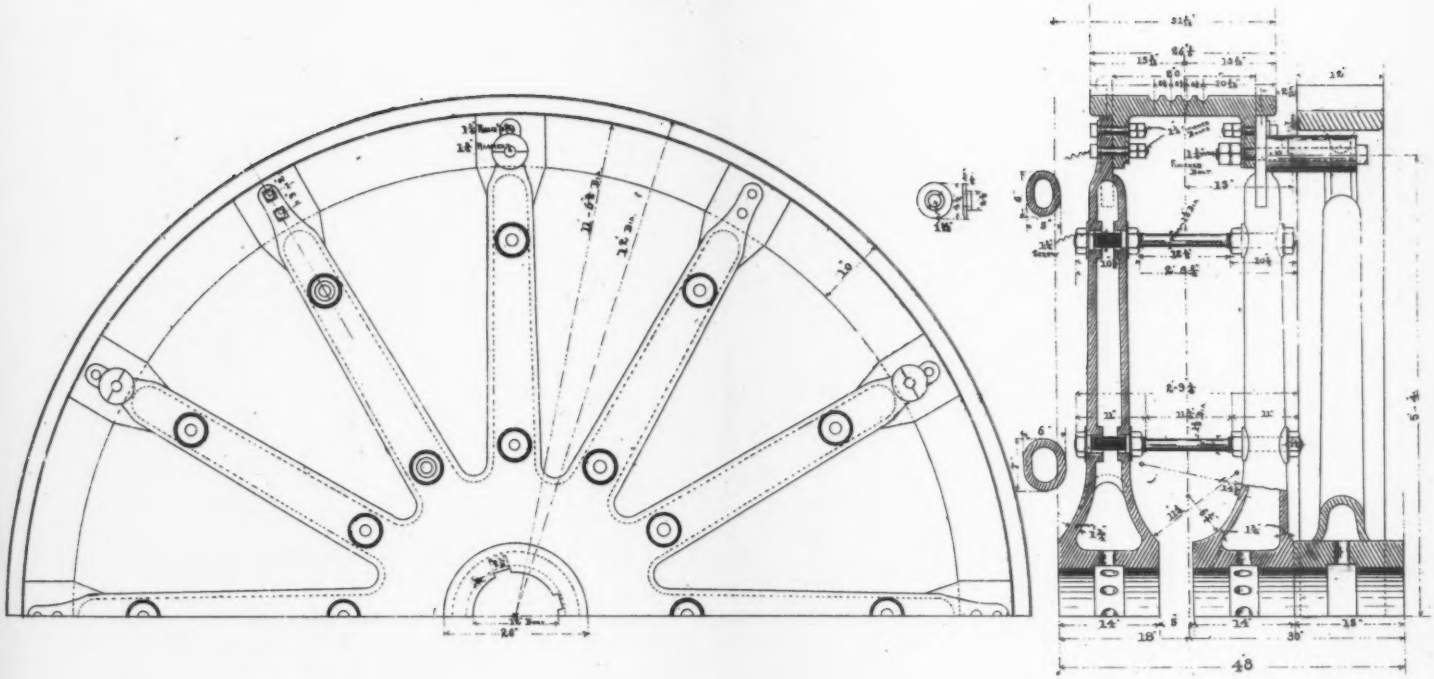
PLAN.

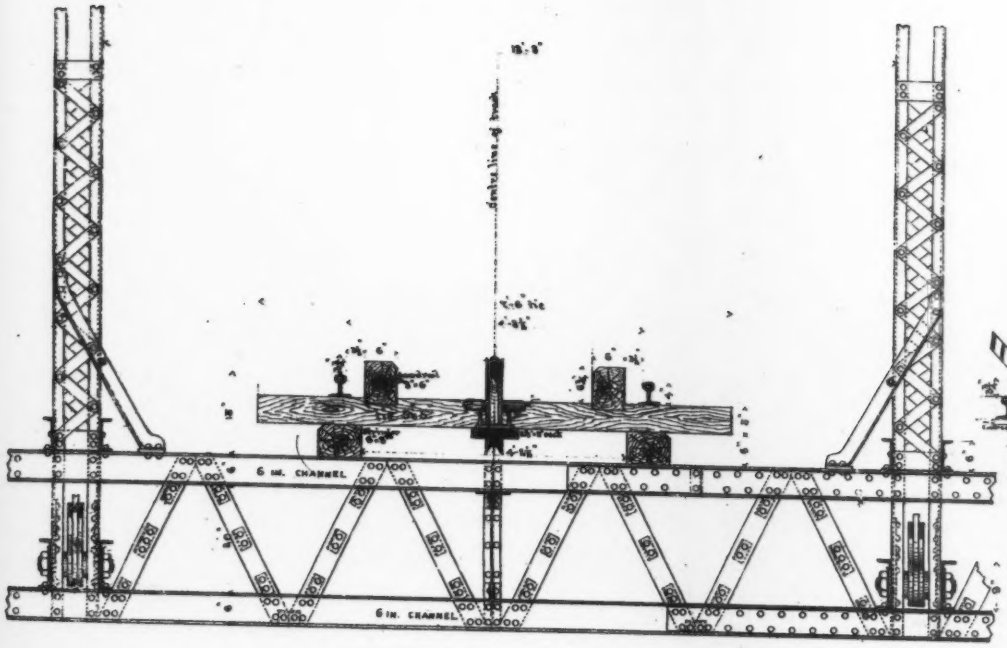


ELEVATION

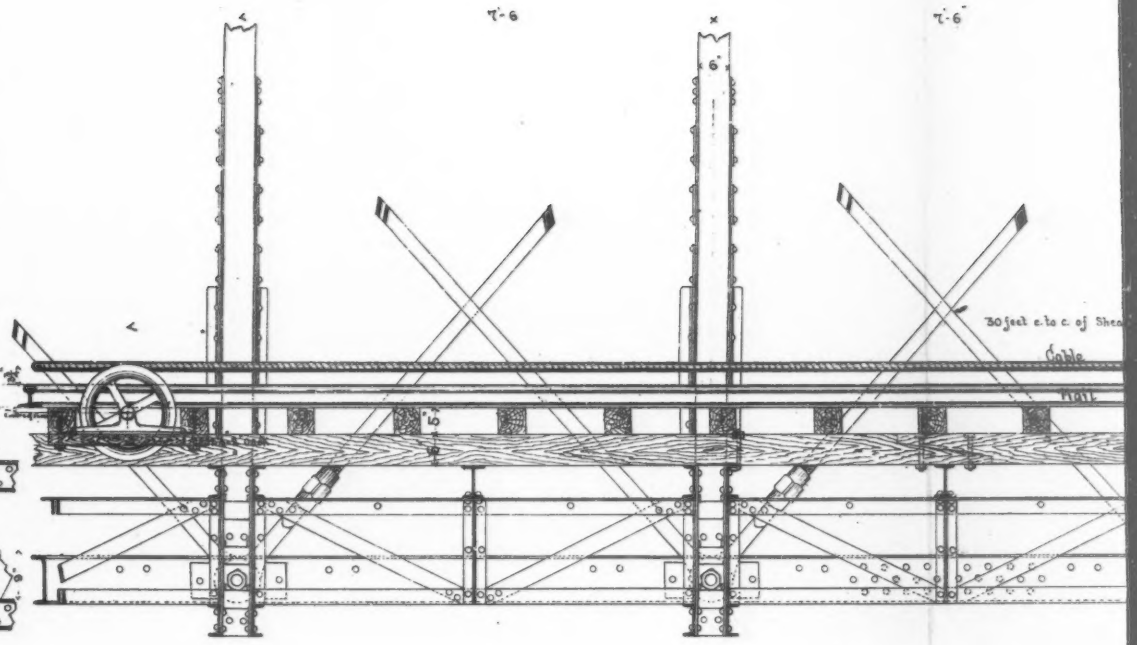
PLATE VI
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

DRUM AND GEAR WHEEL.
AS AFTERWARD MADE.

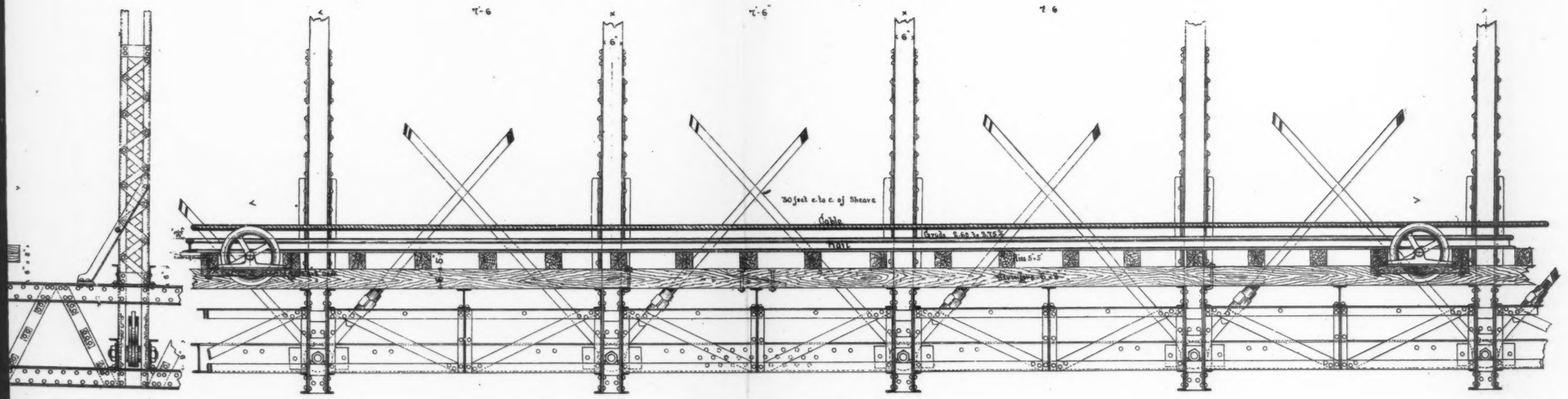




CROSS SECTION OF RAILWAY.



LONGITUDINAL SECTION NEA
6×8 INCH, GUARD-RAIL



LONGITUDINAL SECTION NEAR CENTRE OF TRACK,
6×8 INCH, GUARD-RAIL OMITTED.

PLAN OF NEW YORK STATION.

SHOWING POSITION OF SHEAVES, CABLES AND TRACKS.

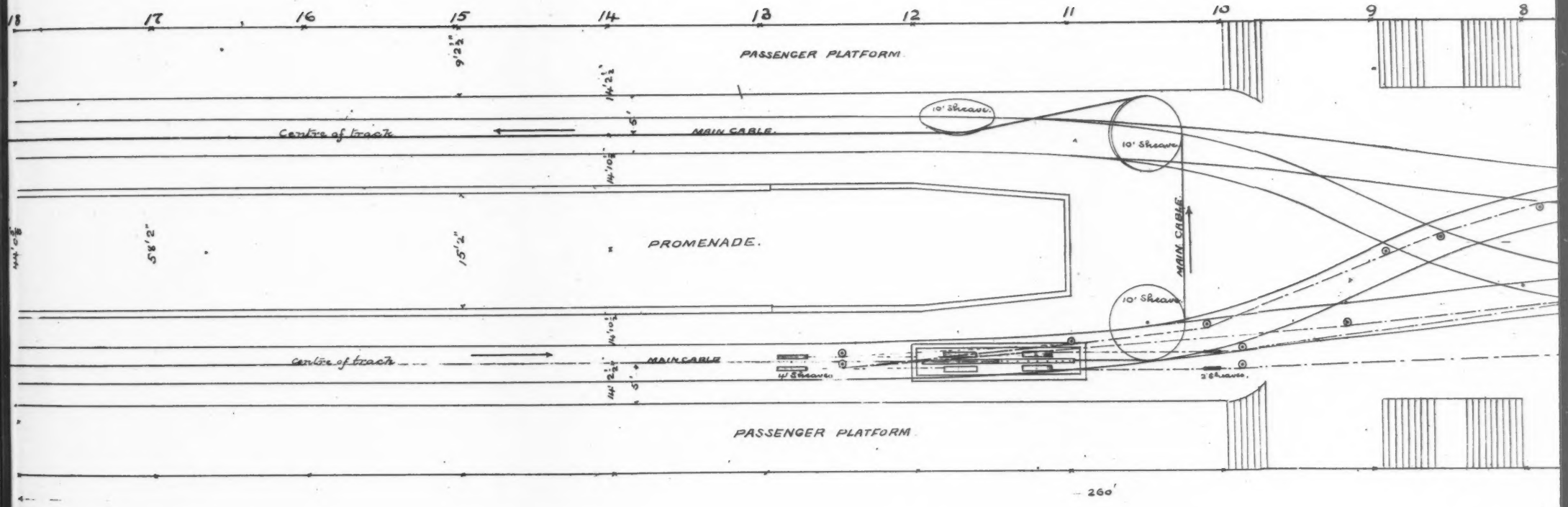


PLATE VIII
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

PLAN OF NEW YORK STATION.

SHOWING POSITION OF SHEAVES, CABLES AND TRACKS.

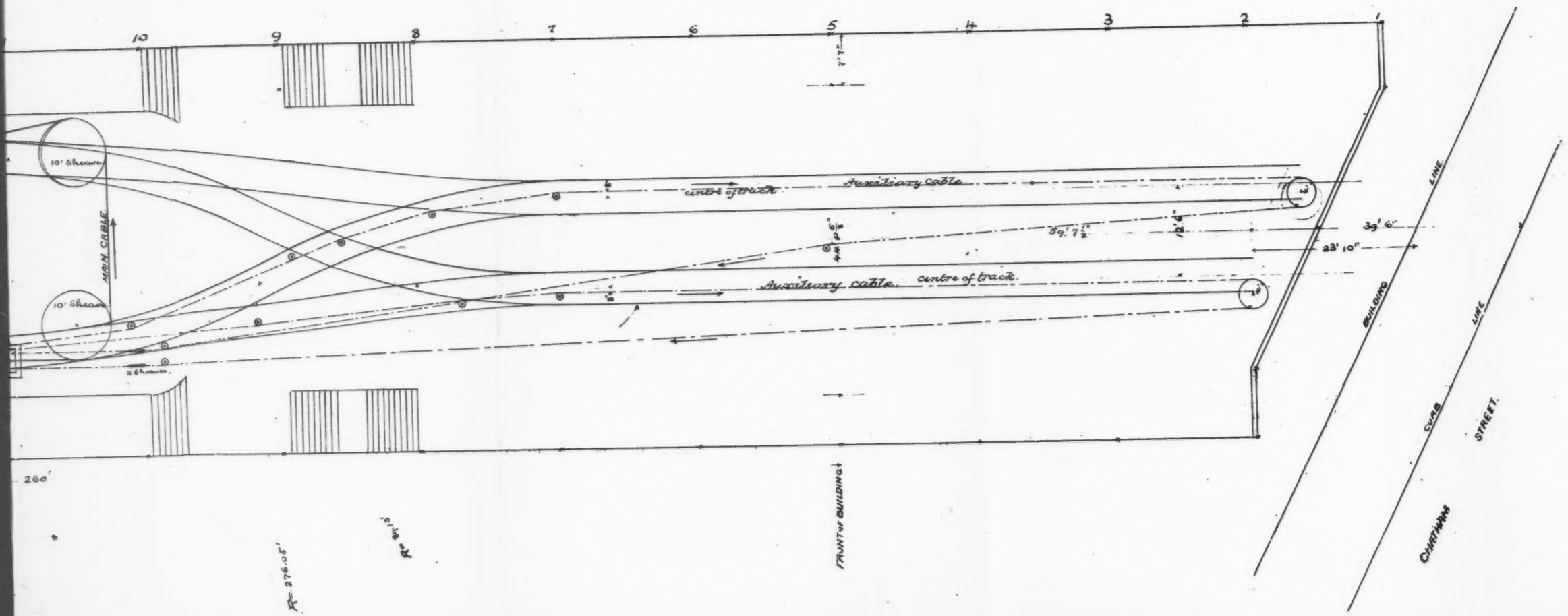
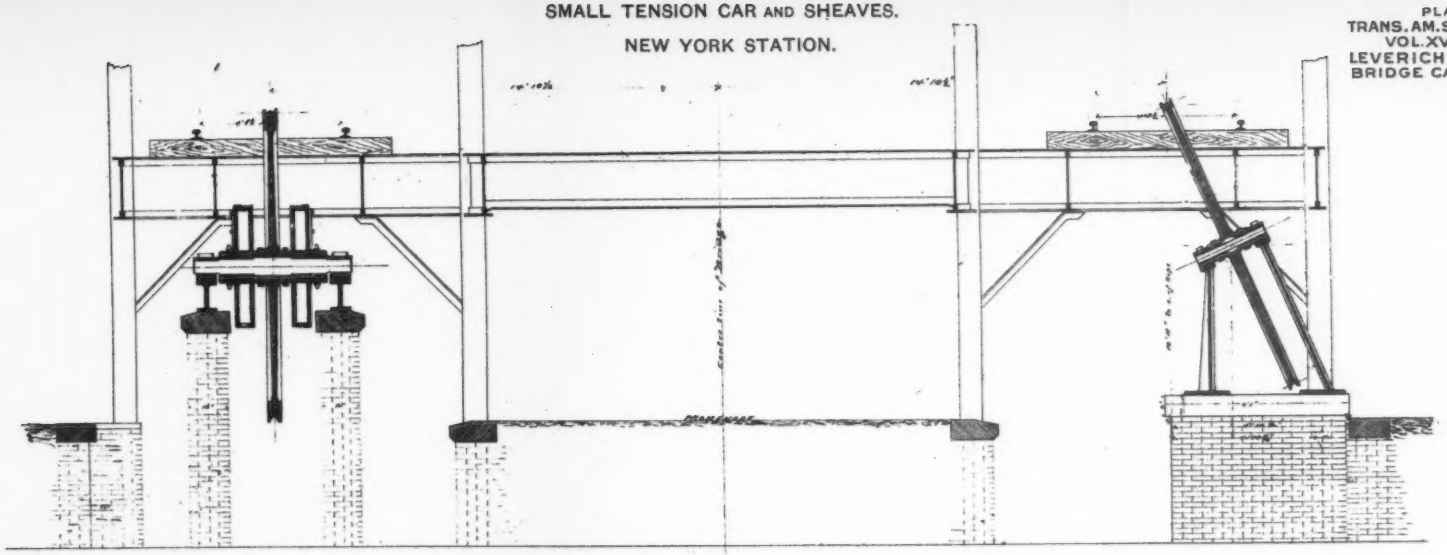
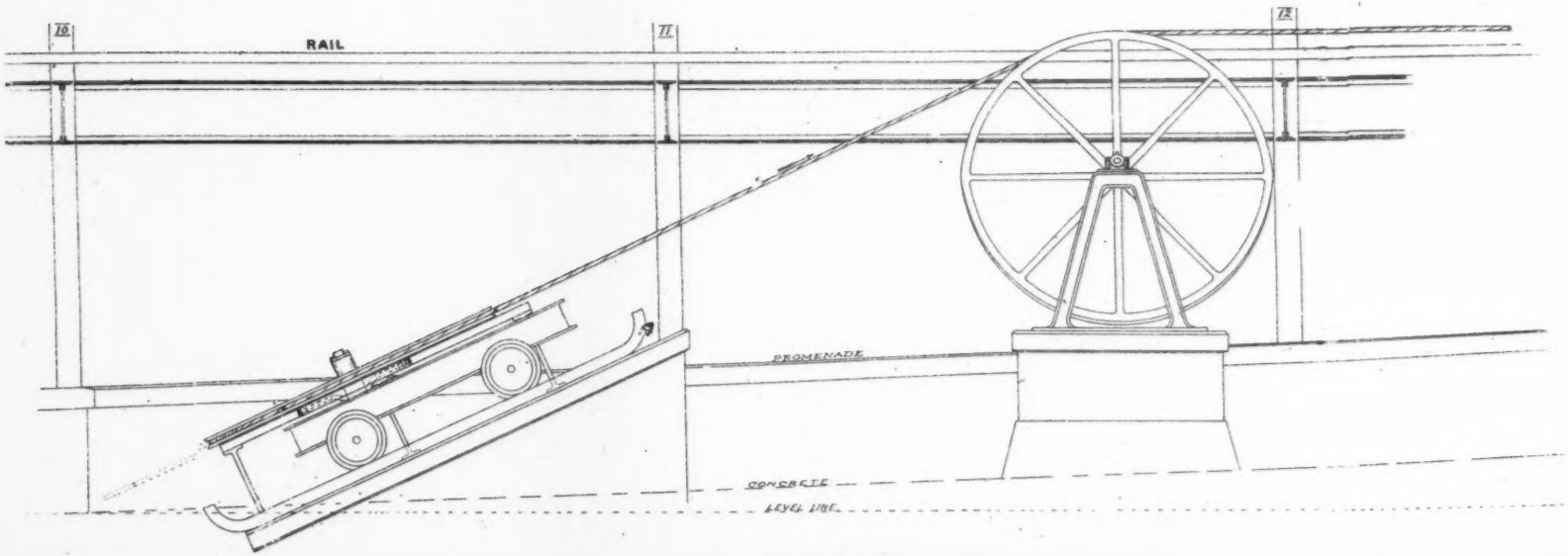


PLATE IX
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

SMALL TENSION CAR AND SHEAVES.
NEW YORK STATION.



CROSS SECTION OF STATION.



SMALL TENSION CAR AND OUTGOING SHEAVE.

SHEAVES FIRST USED,
GROOVE NOT PACKED.

PLATE X
TRANS. AM. SOC. CIV. ENG'NS.
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LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

SHEAVE NOW USED.
GROOVE NOT PACKED.

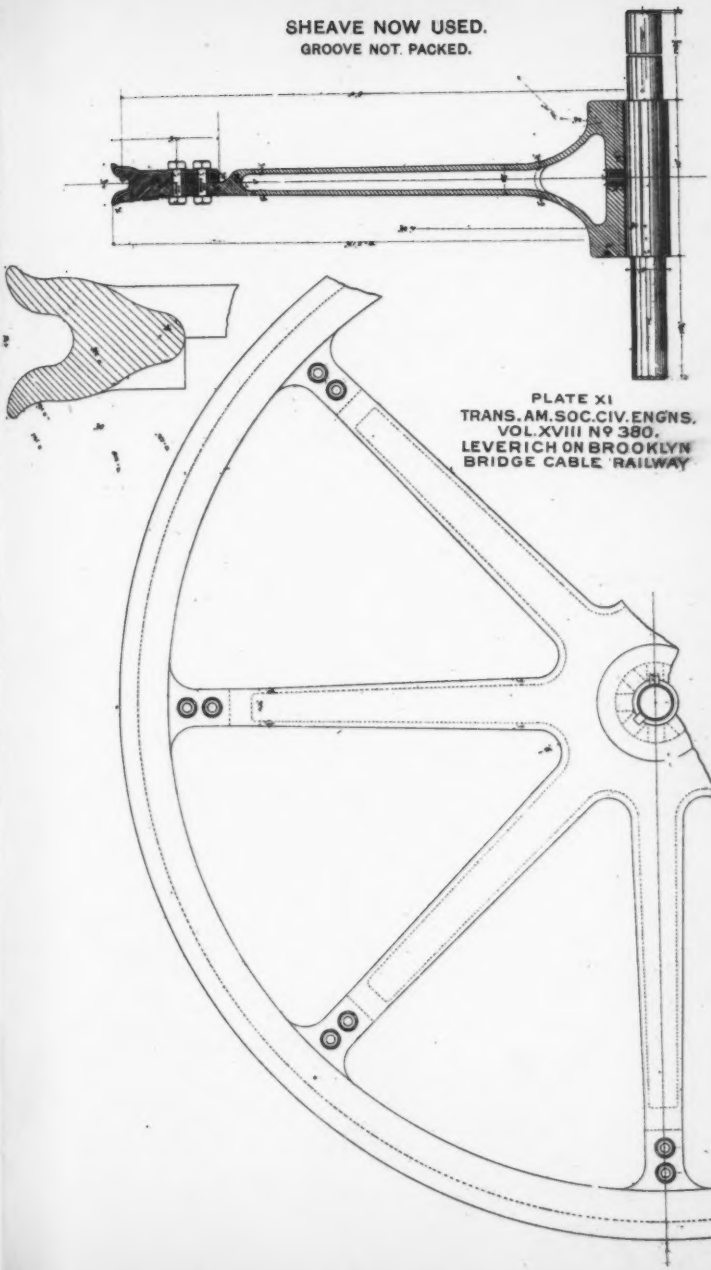
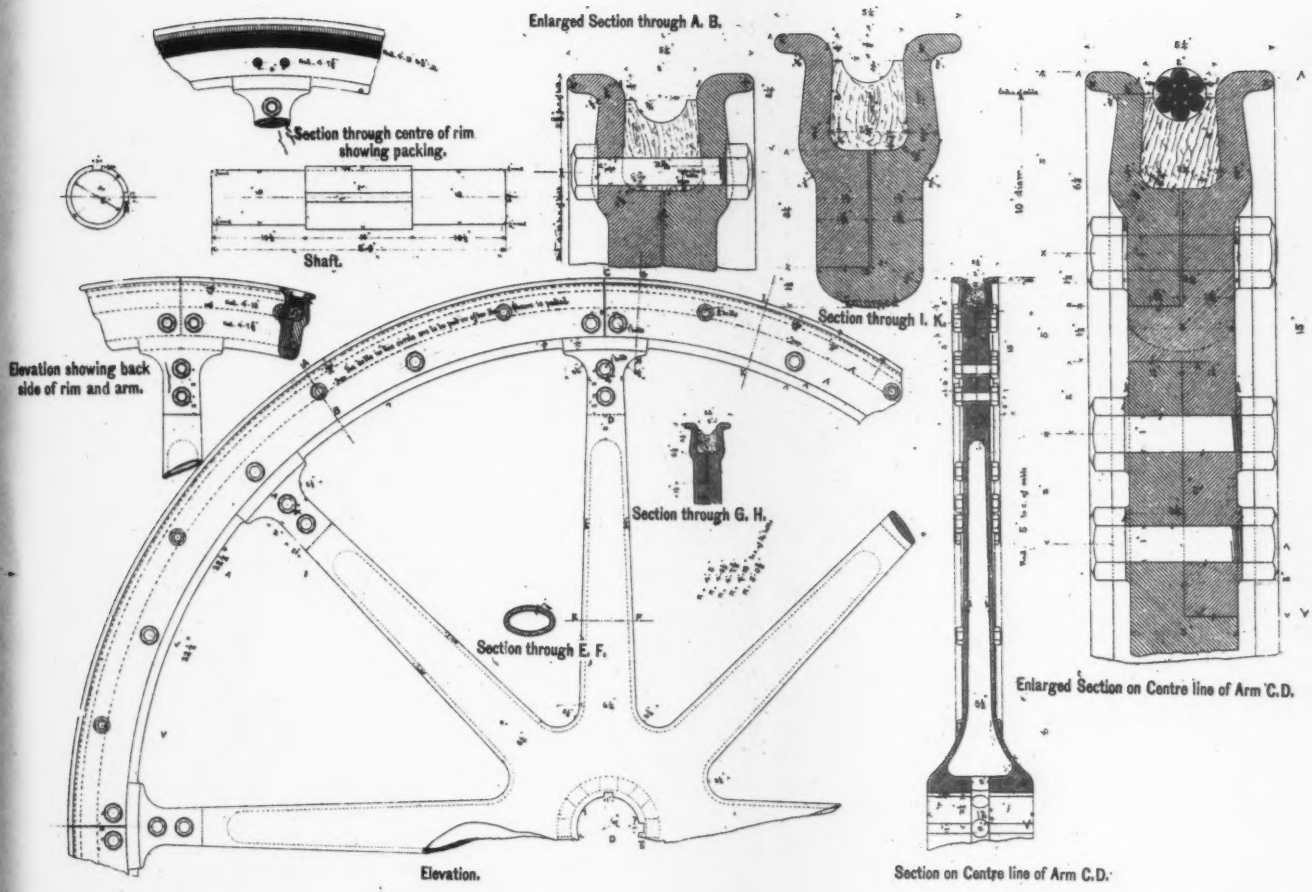


PLATE XI
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

PLATE XII
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY.

SHEAVE NOW USED.
GROOVE PACKED.


Enlarged Section through A. B.
Section through centre of rim showing packing.
Shaft.
Section through I. K.
Elevation showing back side of rim and arm.
Section through G. H.
Section through E. F.
Enlarged Section on Centre line of Arm C.D.
Elevation.
Section on Centre line of Arm C.D.

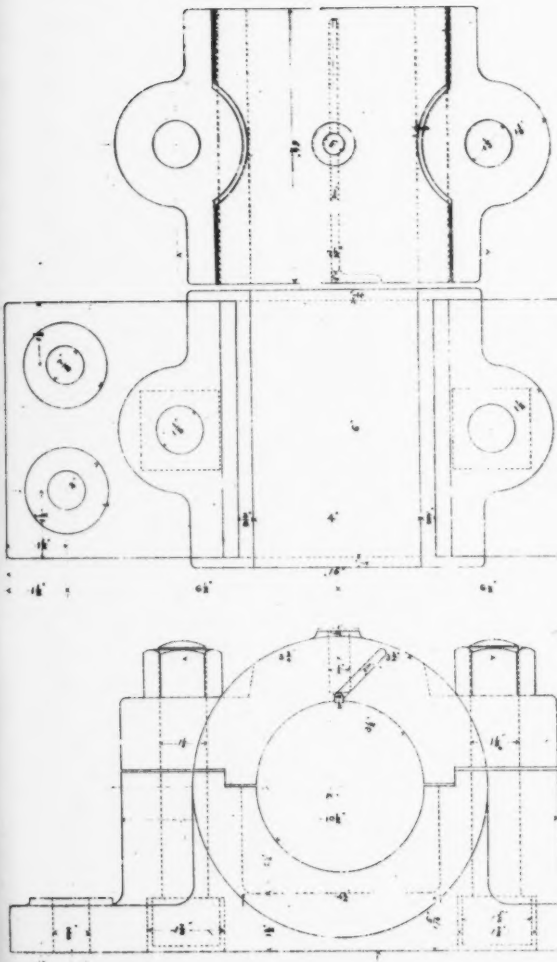


PLATE XIII
TRANS. AM. SOC. CIV. ENG'NS.
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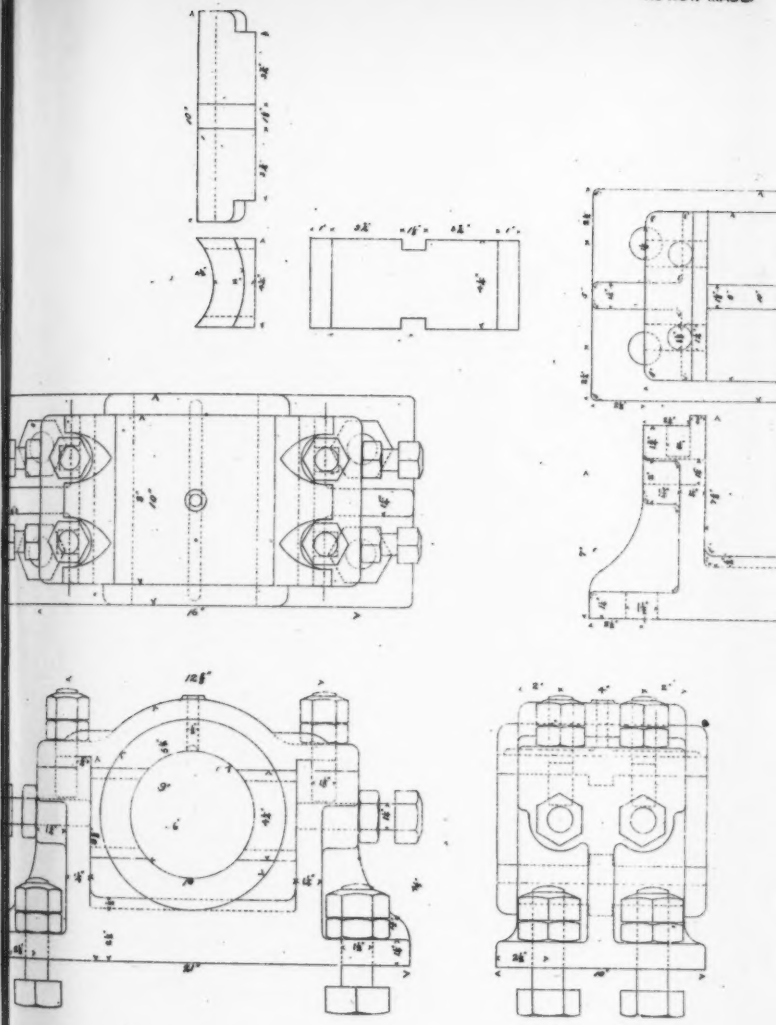
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

SHEAVE PILLOW BLOCK.

AS FIRST MADE.

SHEAVE PILLOW BL

AS NOW MADE.



BLOCK.

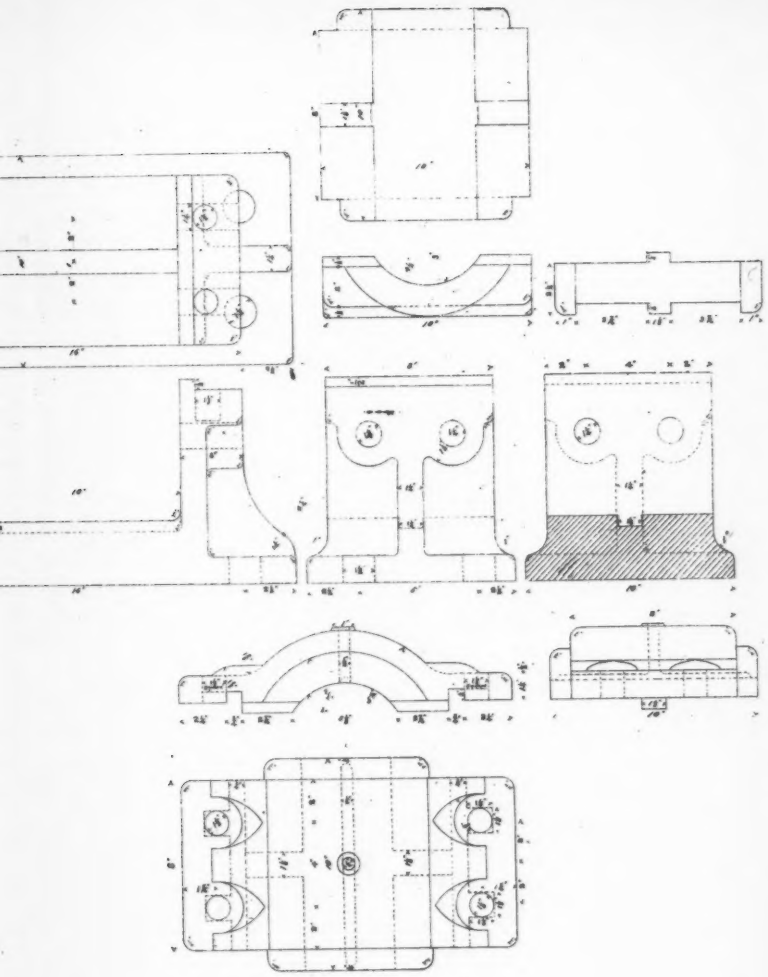


PLATE XV
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

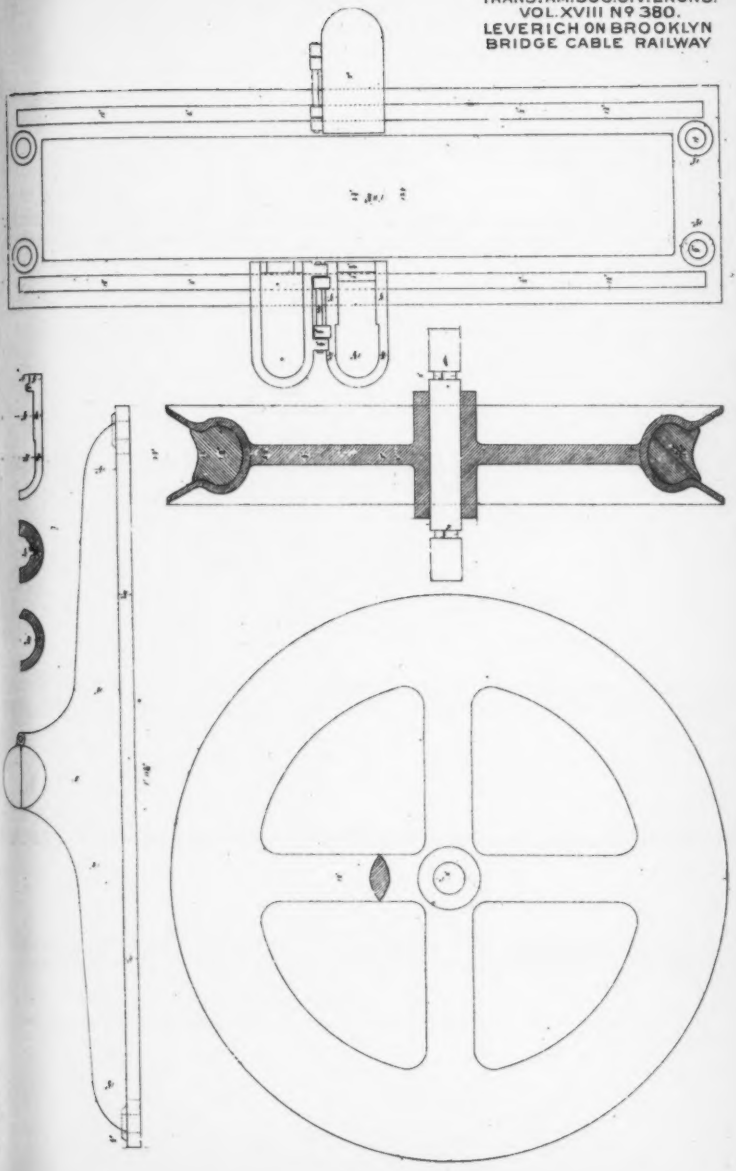
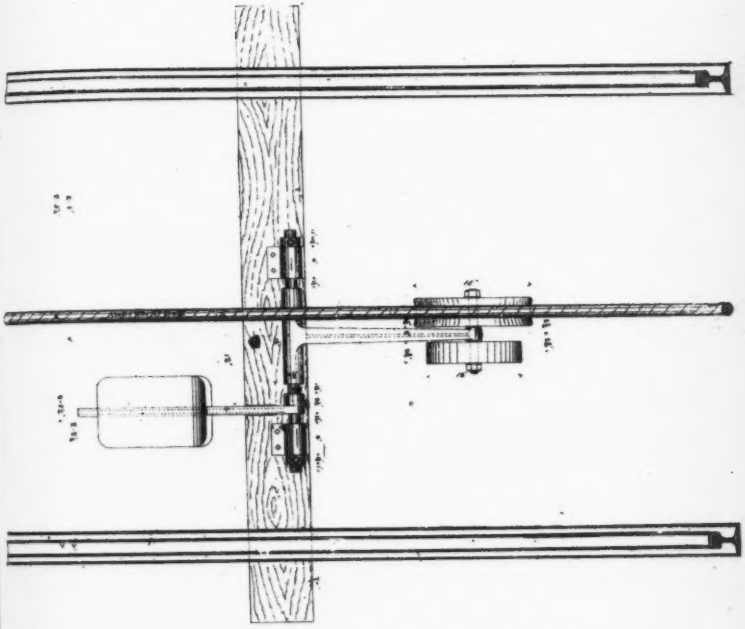
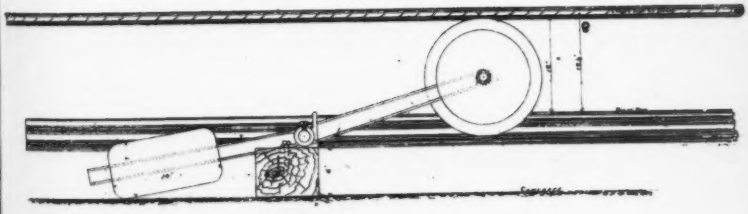


PLATE XVI
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

TILTING PULLEY.



PLAN.

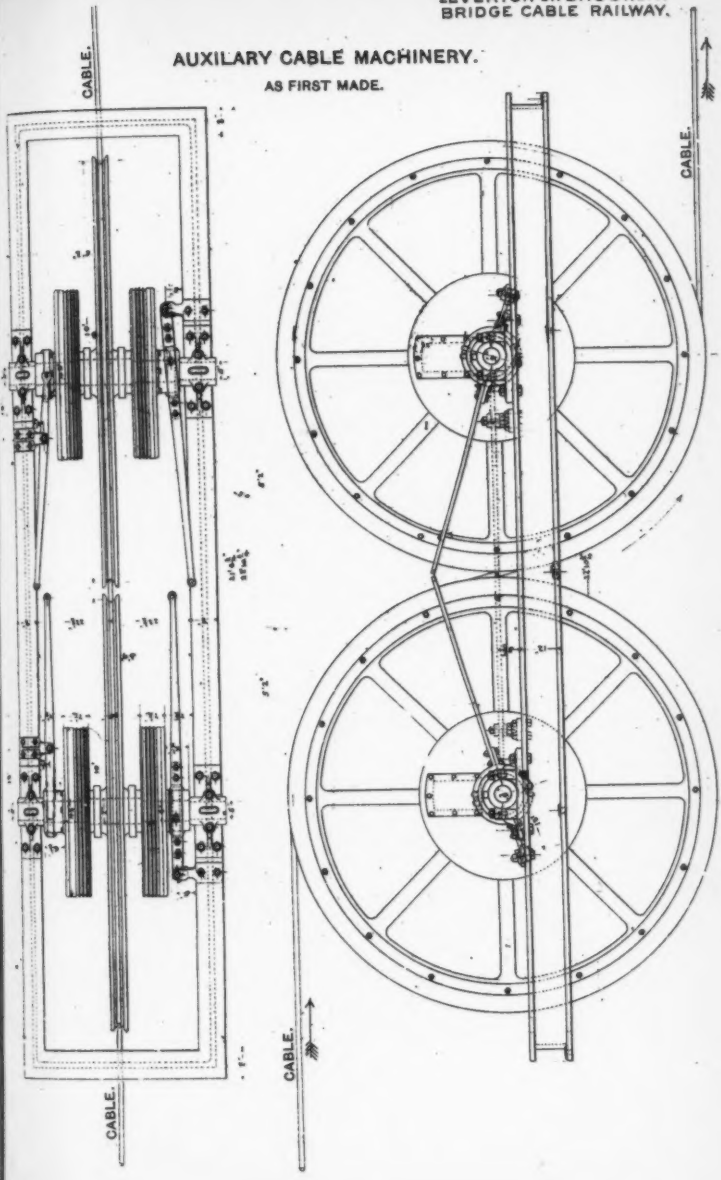


ELEVATION.

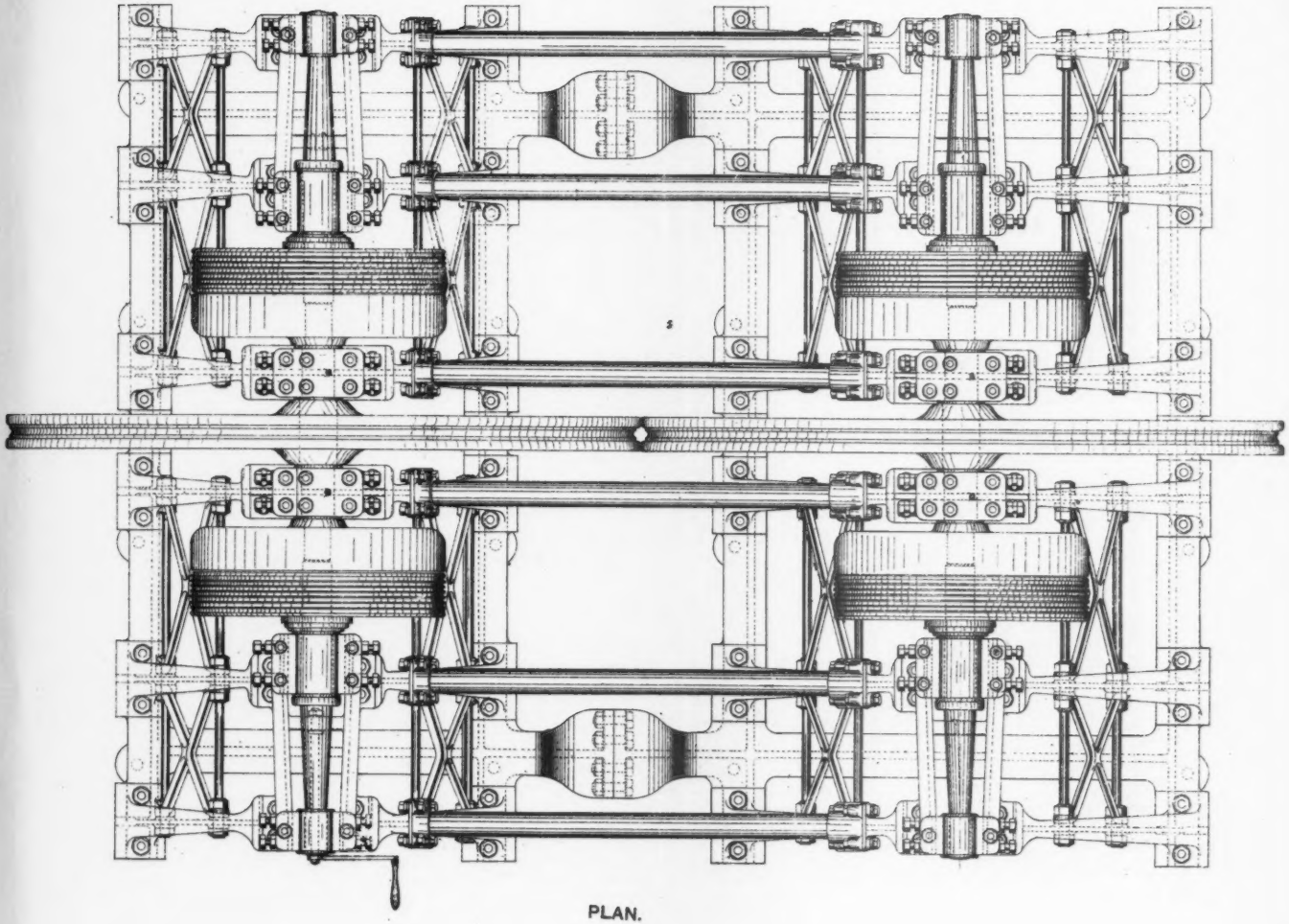
PLATE XVII
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY.

AUXILARY CABLE MACHINERY.

AS FIRST MADE.

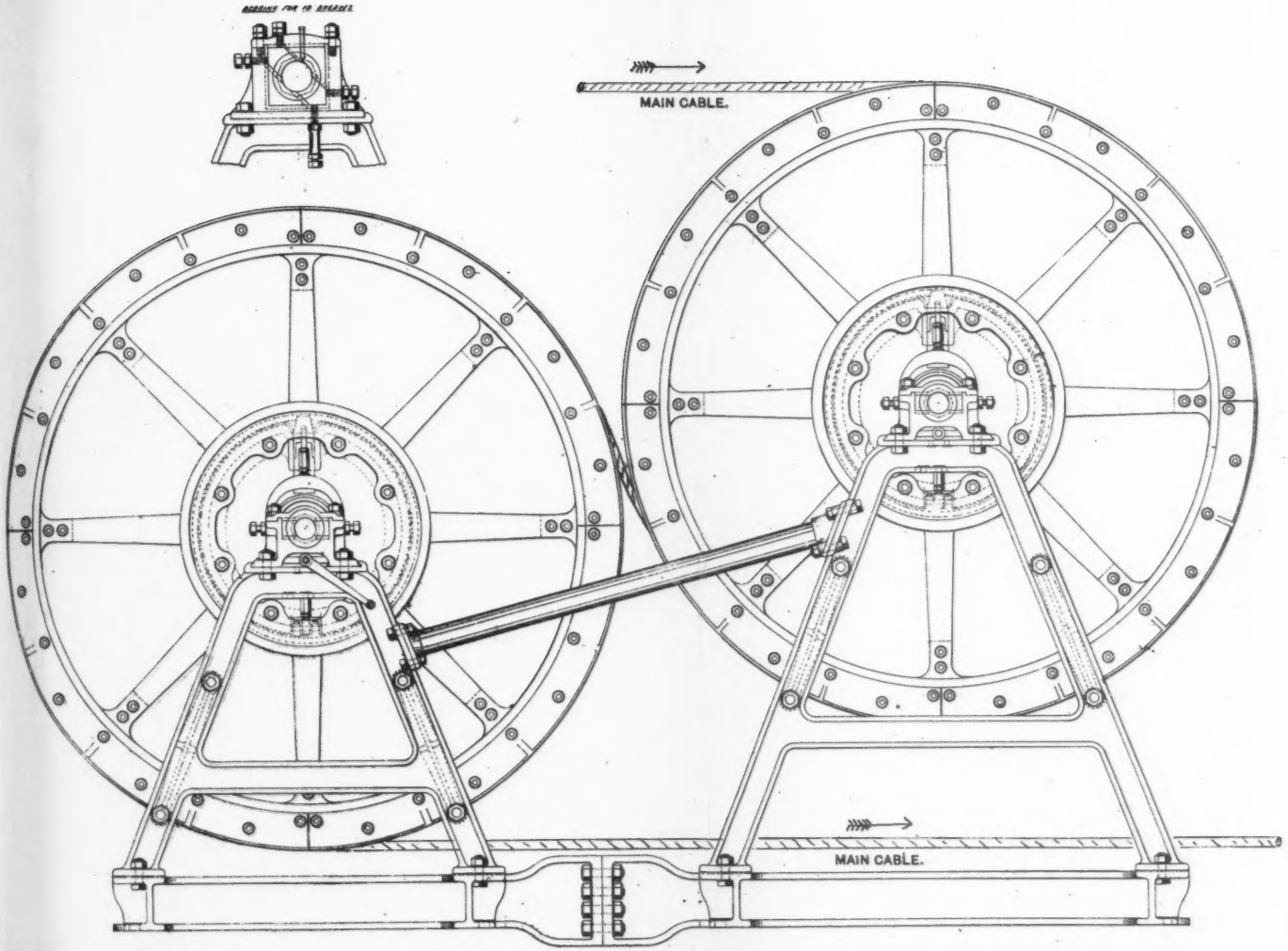


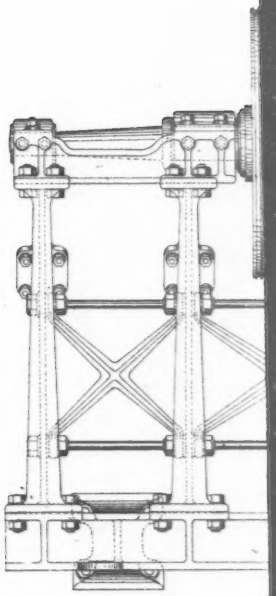
AUXILARY CABLE MACHINERY.
AS AFTERWARD MADE.



PLAN.

AUXILIARY CABLE-MACHINERY.
AS AFTERWARD MADE.

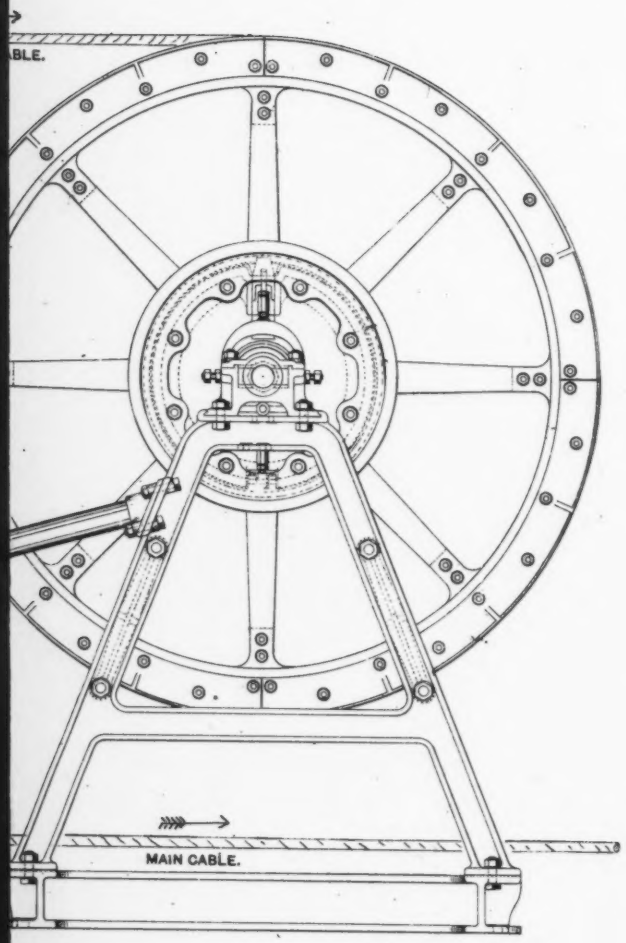


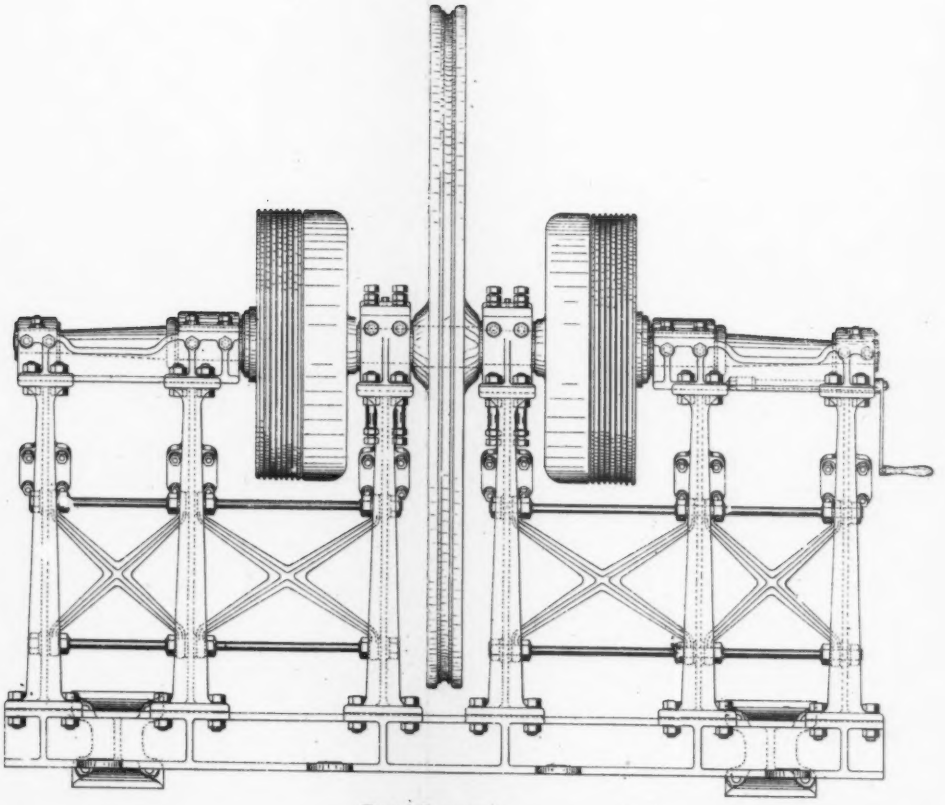


SIDE ELEVATION.

PLATE XIX
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

AUXILIARY CABLE-MACHINERY.
AS AFTERWARD MADE.





FRONT ELEVATION.

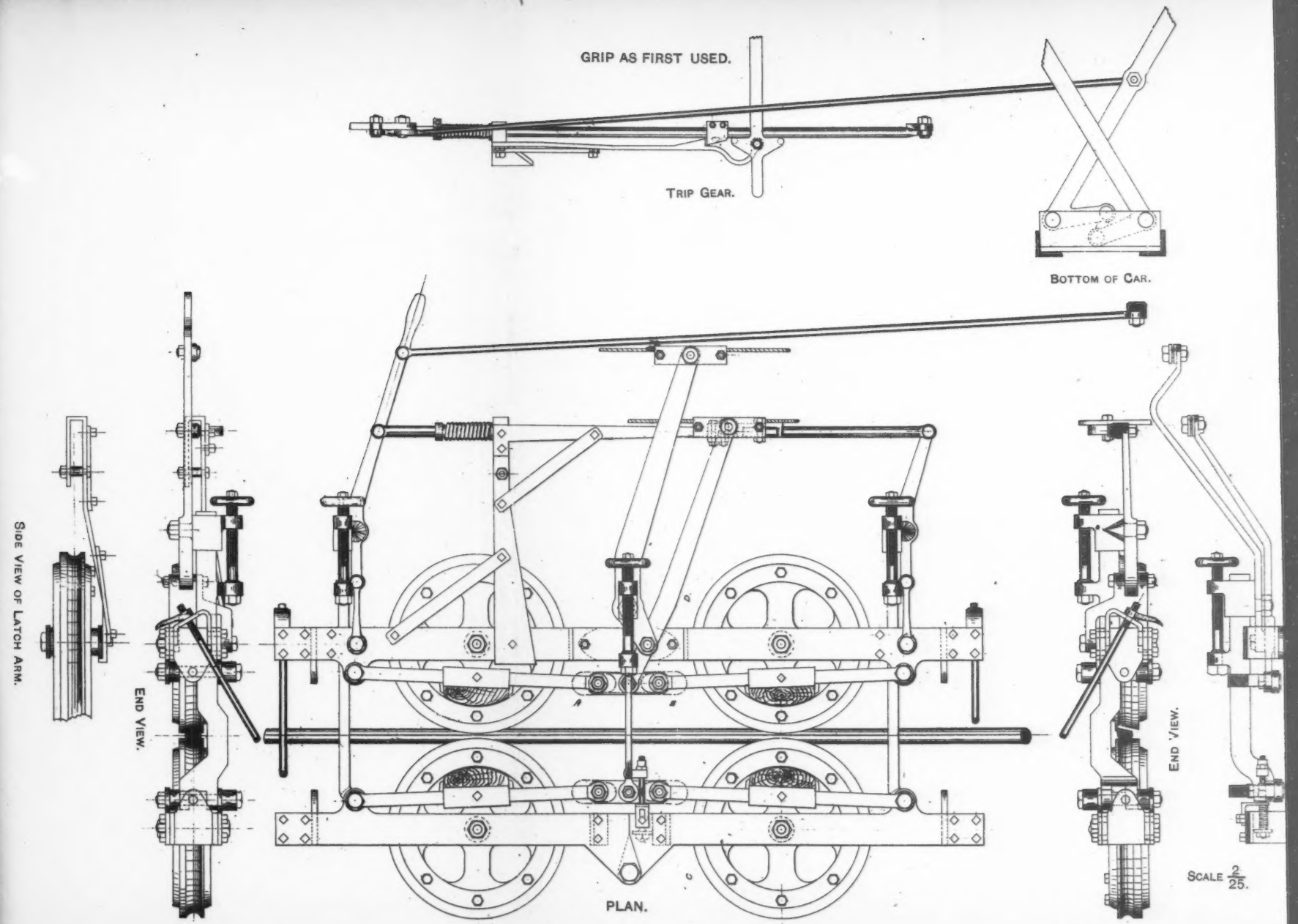
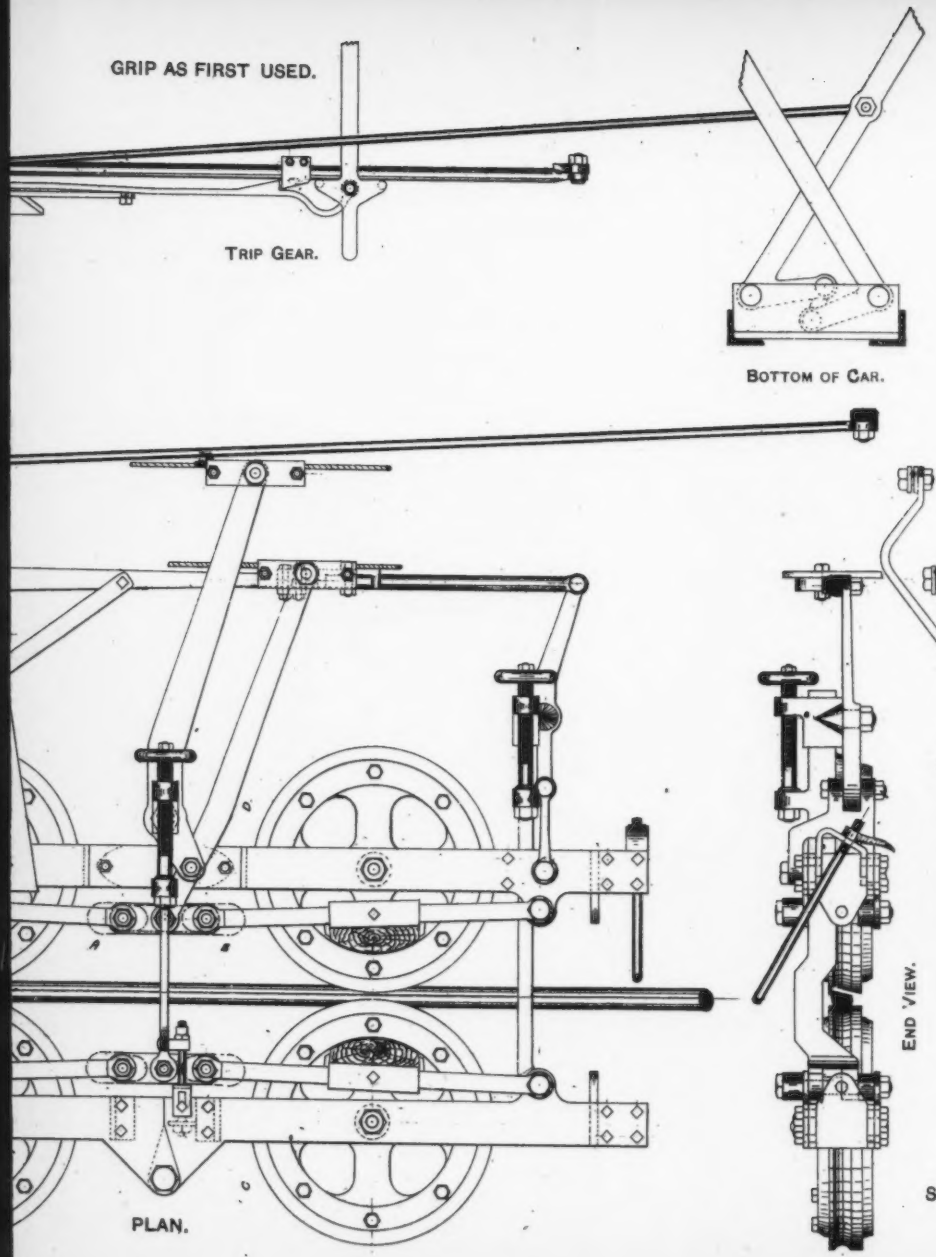
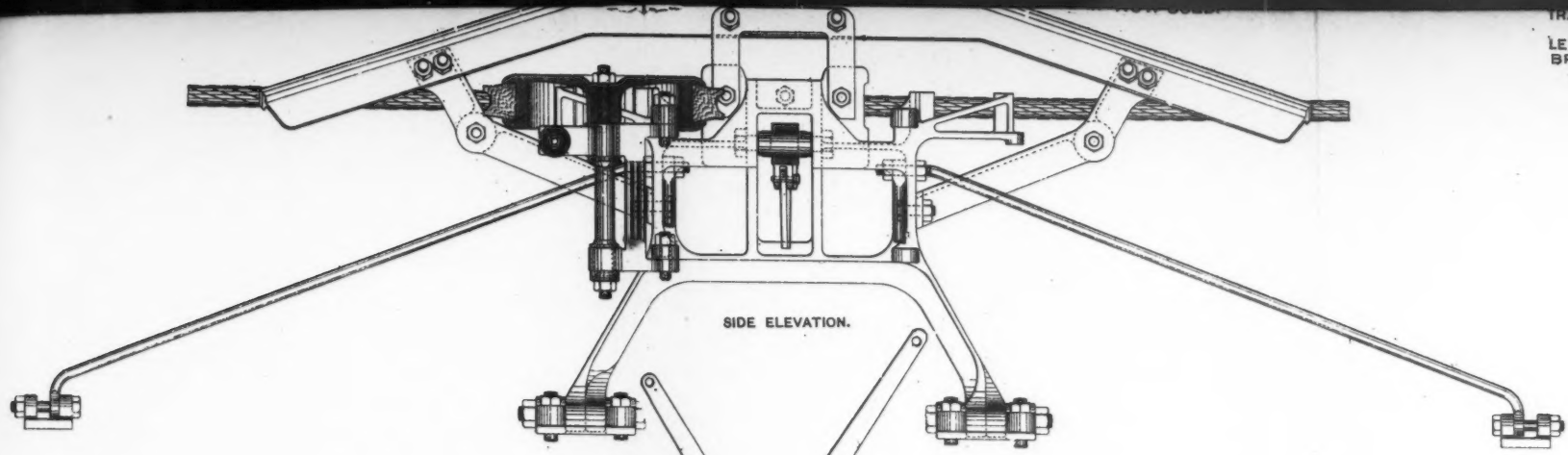

GRIP AS FIRST USED.
TRIP GEAR.
BOTTOM OF CAR.
SIDE VIEW OF LATCH ARM.
END VIEW.
PLAN.
END VIEW.
SCALE 2/25.

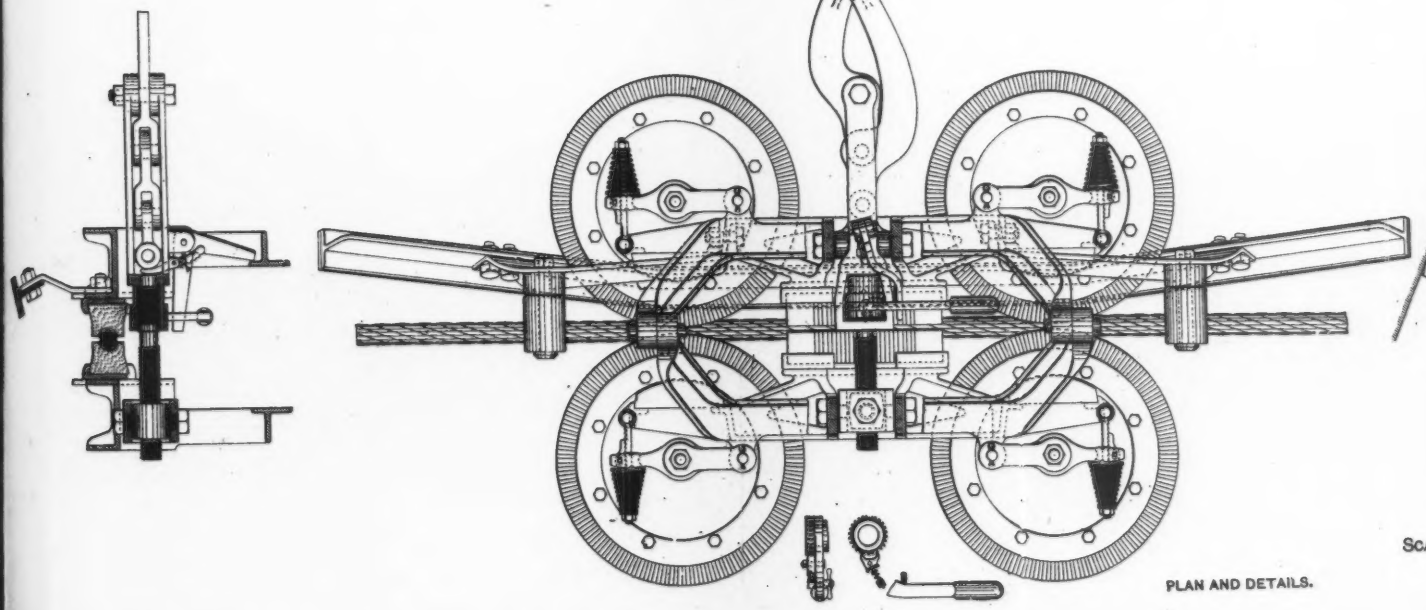
PLATE XX
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY



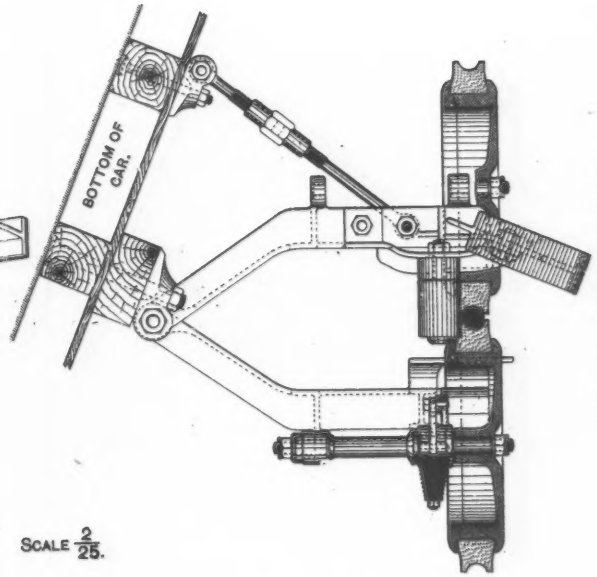
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY



SIDE ELEVATION.



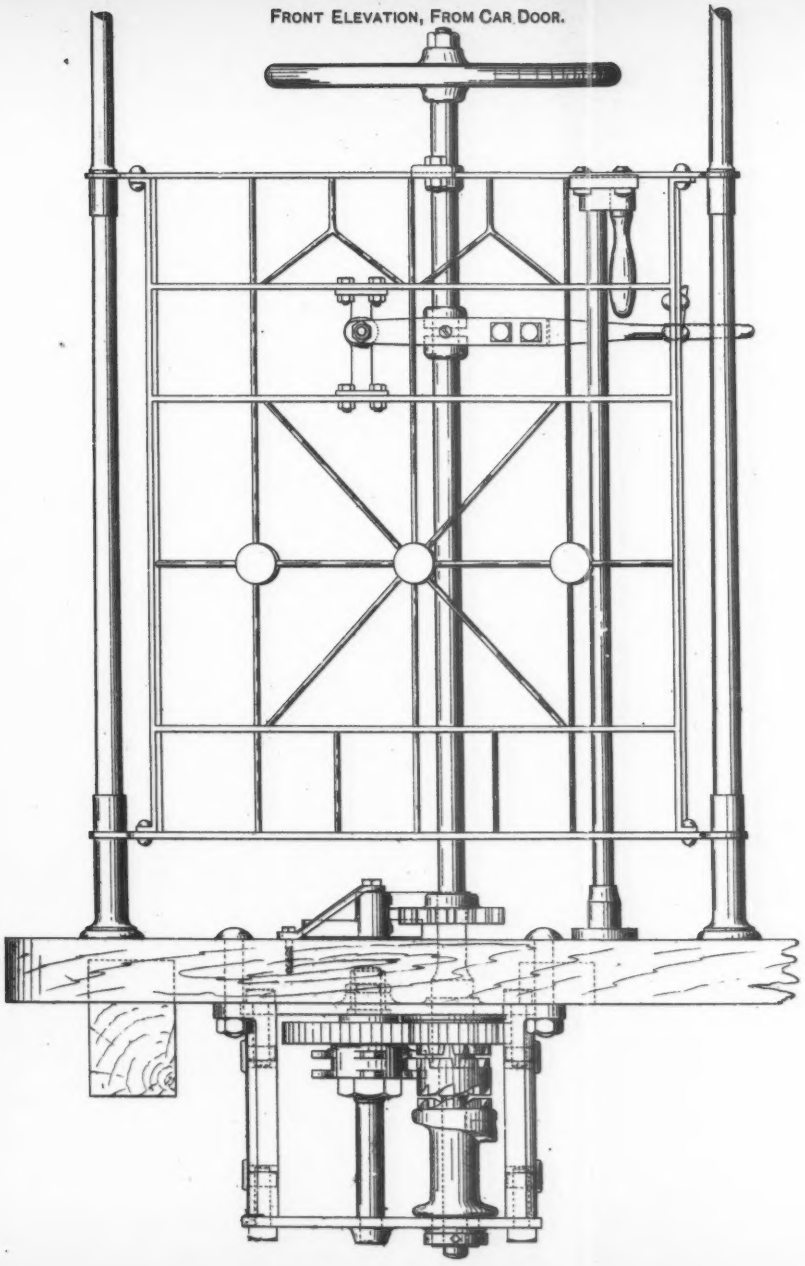
PLAN AND DETAILS.



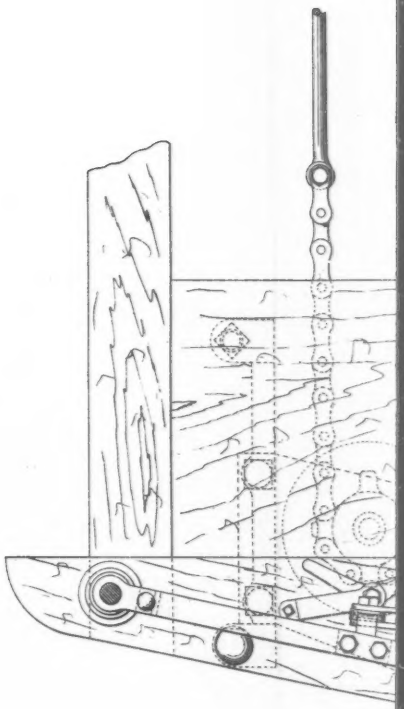
SECTION THROUGH PULLEYS

SCALE $\frac{2}{25}$.

FRONT ELEVATION, FROM CAR DOOR.

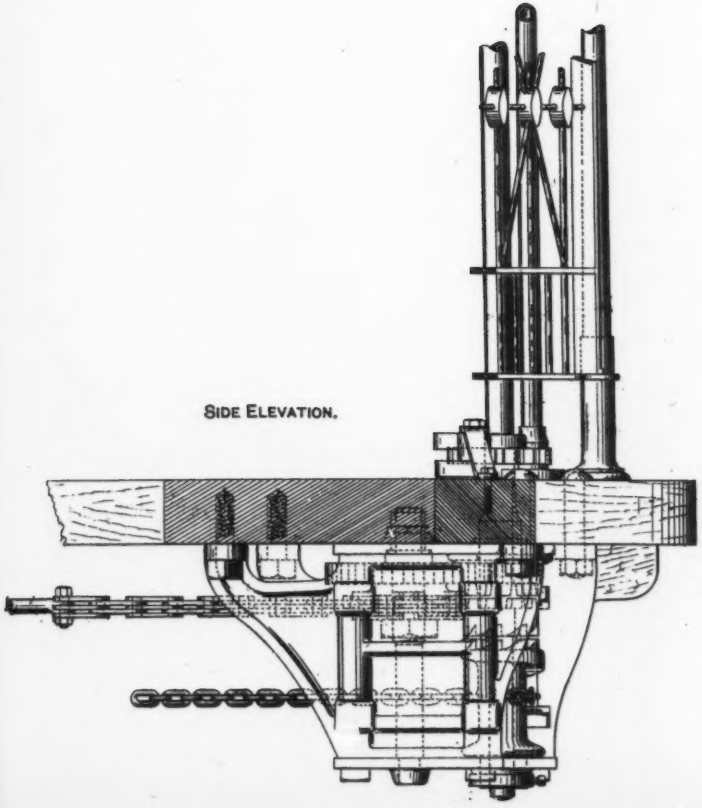


GEAR FOR OPERATING GRIP AND BRAK

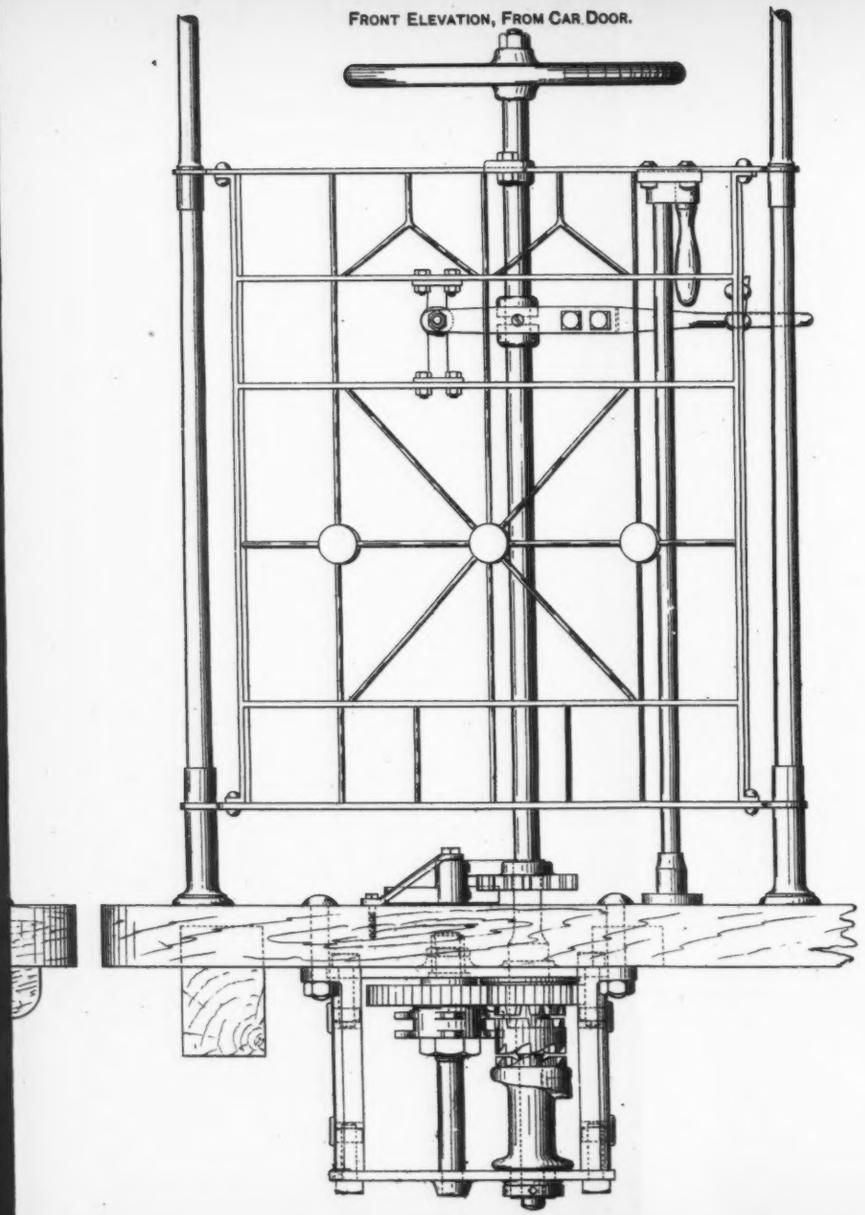


PLAN

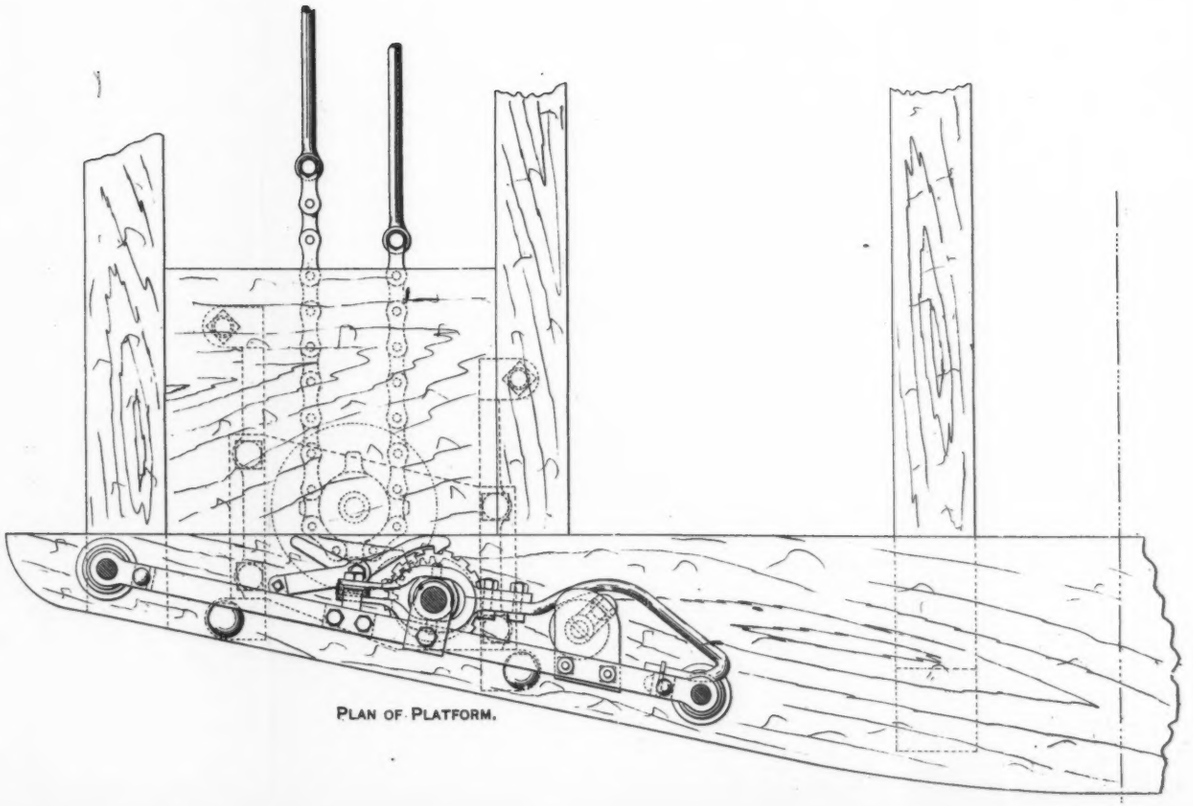
SIDE ELEVATION.



FRONT ELEVATION, FROM CAR DOOR.



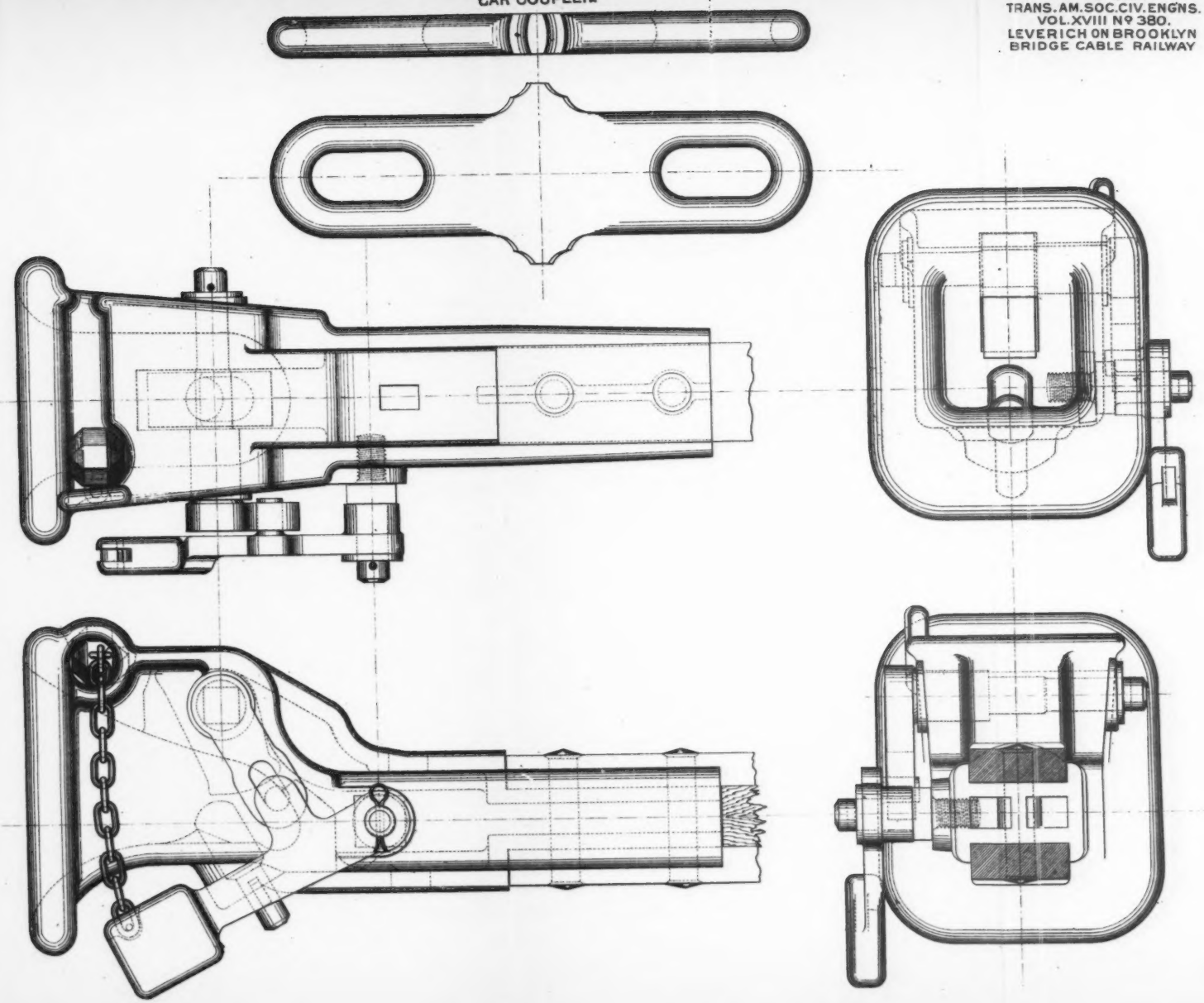
GEAR FOR OPERATING GRIP AND BRAKES.



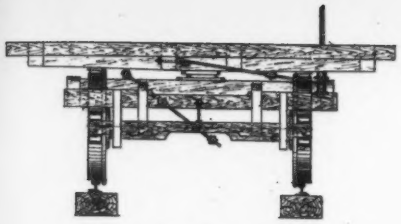
PLAN OF PLATFORM.

CAR COUPLER.

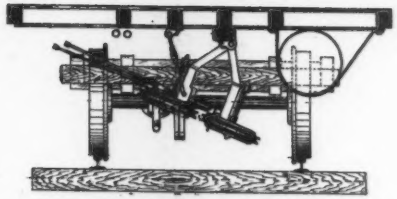
PLATE XXIII
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY



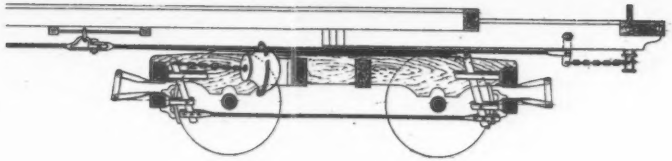
CAR BOTTOM AND TRUCKS.



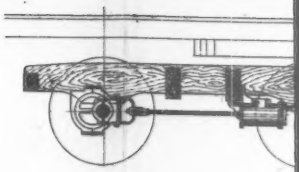
END VIEW SHOWING
BRAKE RODS.



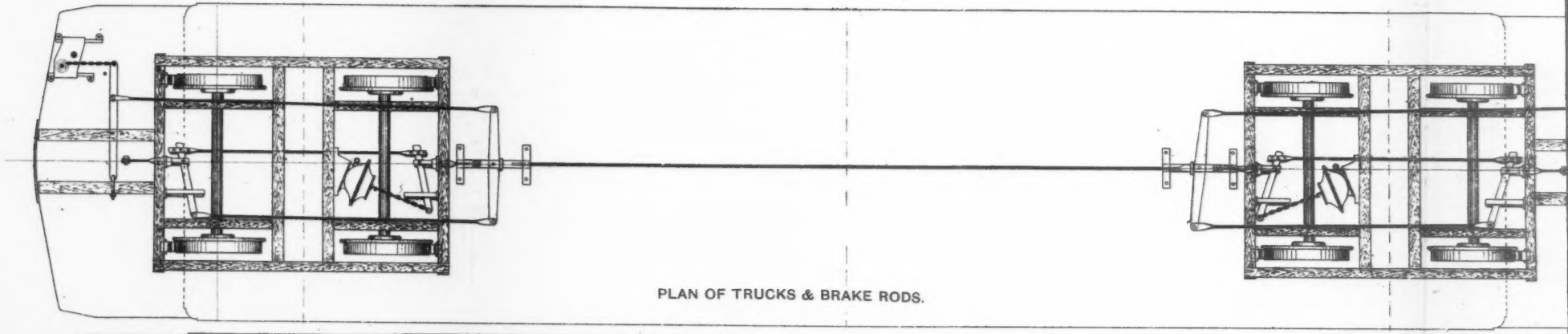
CROSS SECTION SHOWING
GRIP, VACUUM PUMP & RESERVOIR.



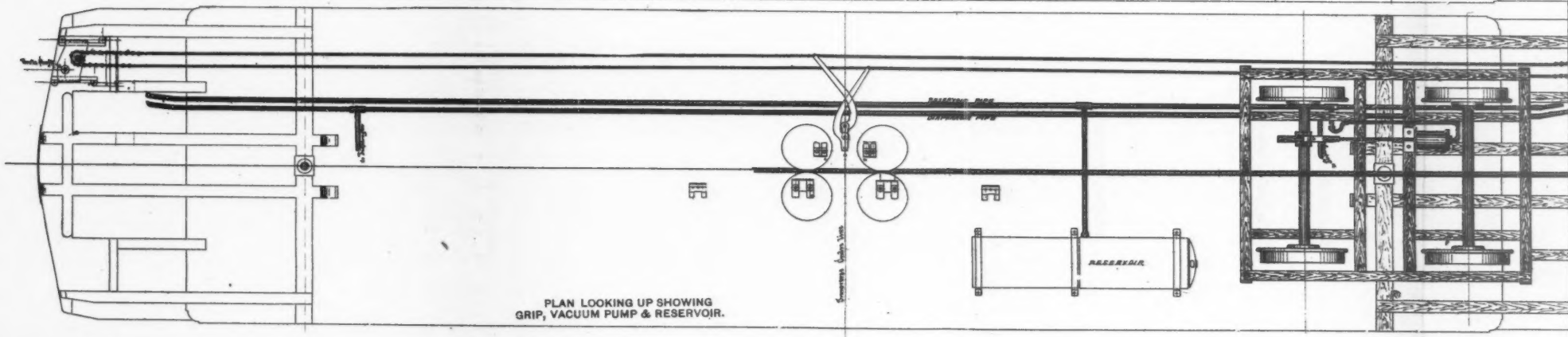
CENTRAL LONGITUDINAL SECTION OF TRUCK, SHOWING
BRAKES, BRAKE LEVERS & DIAPHRAGM.



CENTRAL LONGITUDINAL SECTION OF T



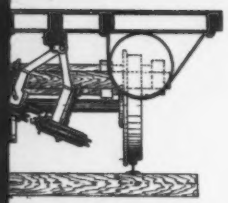
PLAN OF TRUCKS & BRAKE RODS.



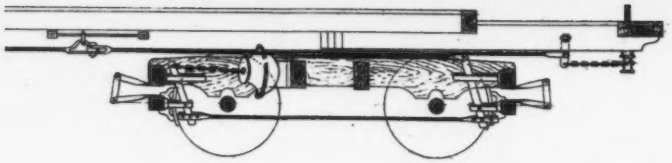
PLAN LOOKING UP SHOWING
GRIP, VACUUM PUMP & RESERVOIR.

PLATE XXIV
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

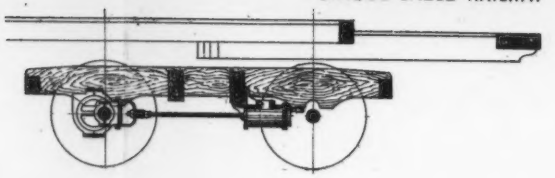
CAR BOTTOM AND TRUCKS.



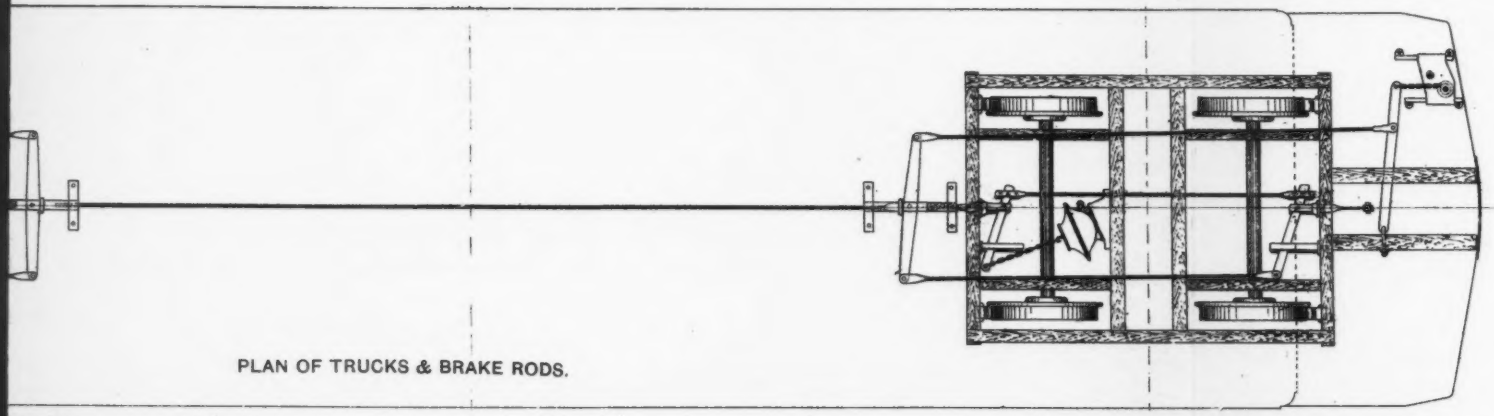
CTION SHOWING
PUMP & RESERVOIR.



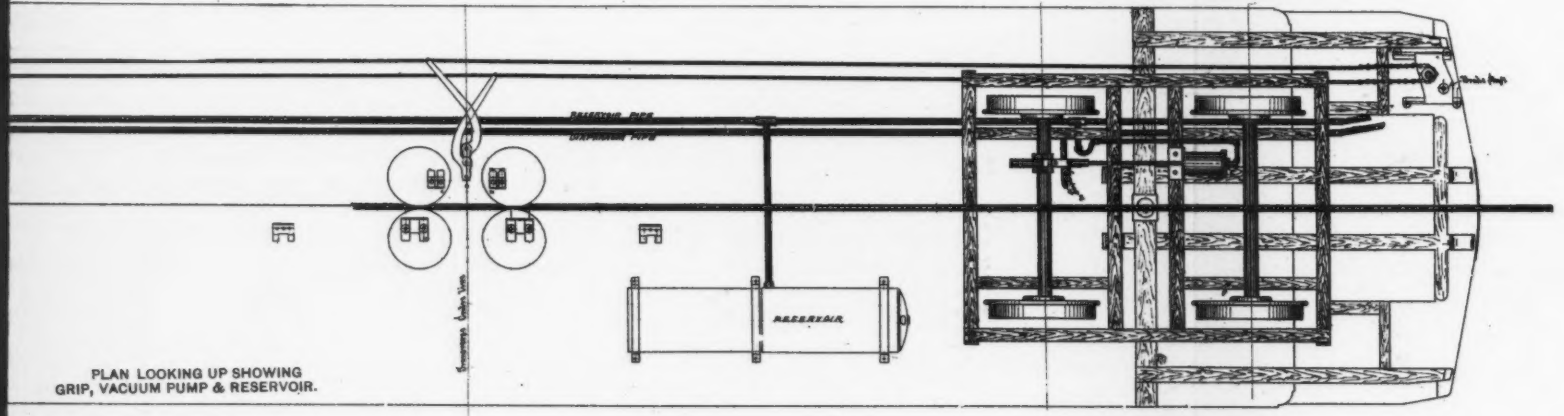
CENTRAL LONGITUDINAL SECTION OF TRUCK, SHOWING
BRAKES, BRAKE LEVERS & DIAPHRAGM.



CENTRAL LONGITUDINAL SECTION OF TRUCK, SHOWING VACUUM PUMP



PLAN OF TRUCKS & BRAKE RODS.

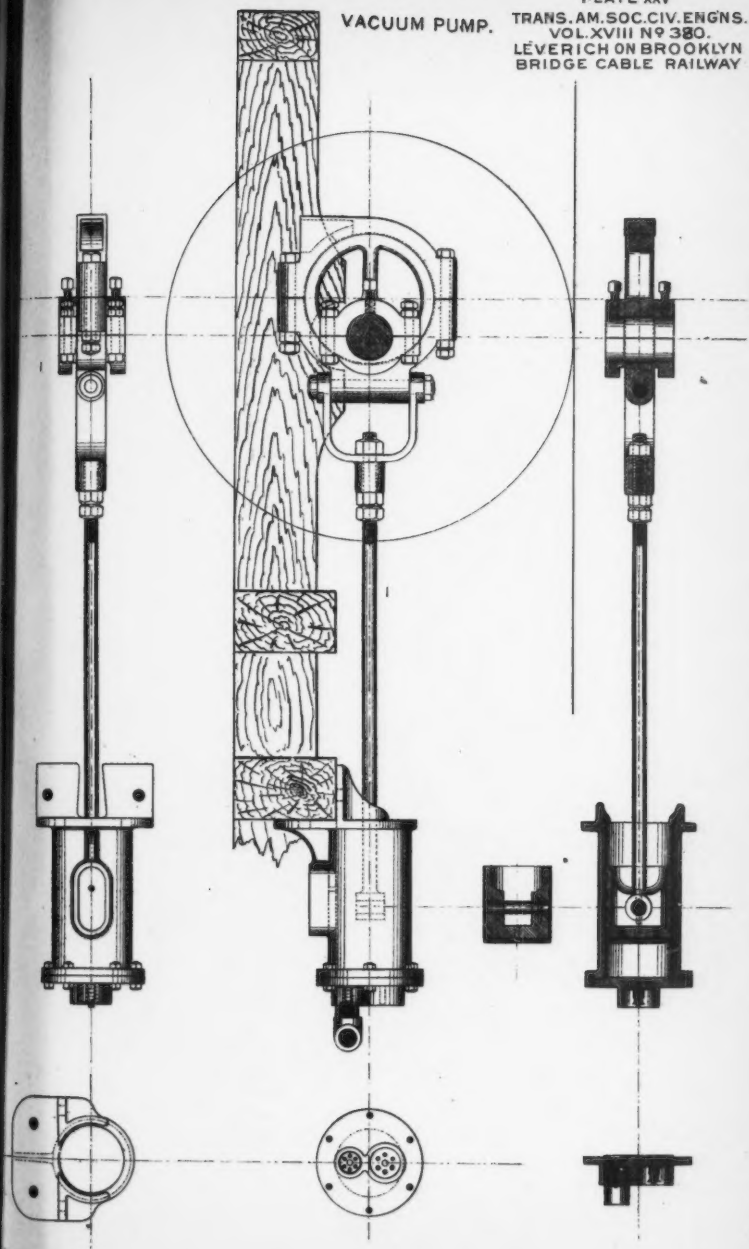


PLAN LOOKING UP SHOWING
GRIP, VACUUM PUMP & RESERVOIR.

PLATE XXV

TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

VACUUM PUMP.



PROFILE OF CABLE RAILWAY.

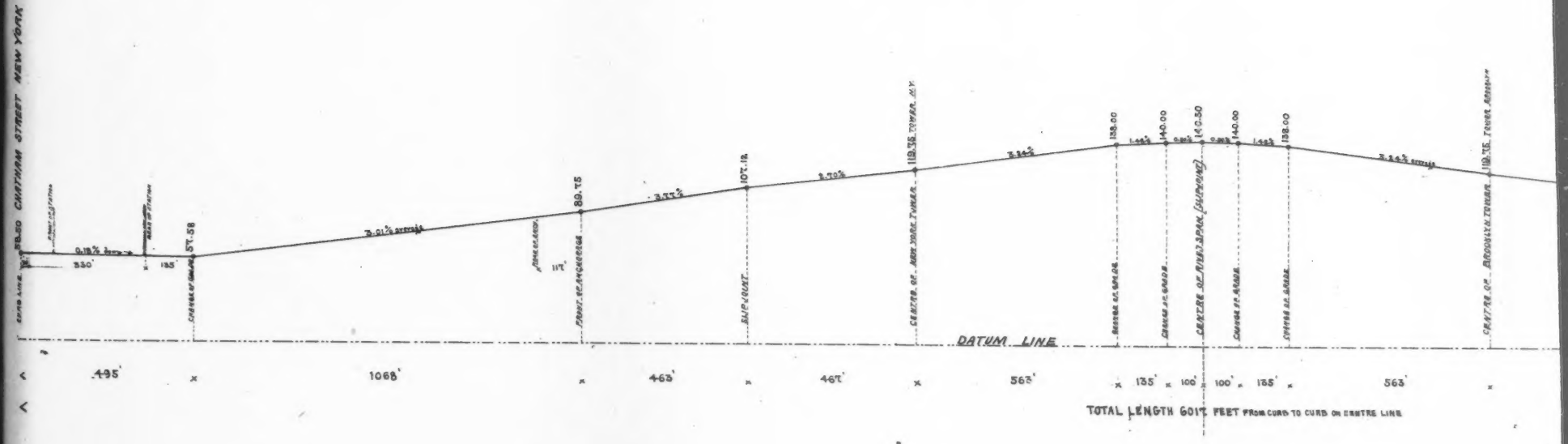
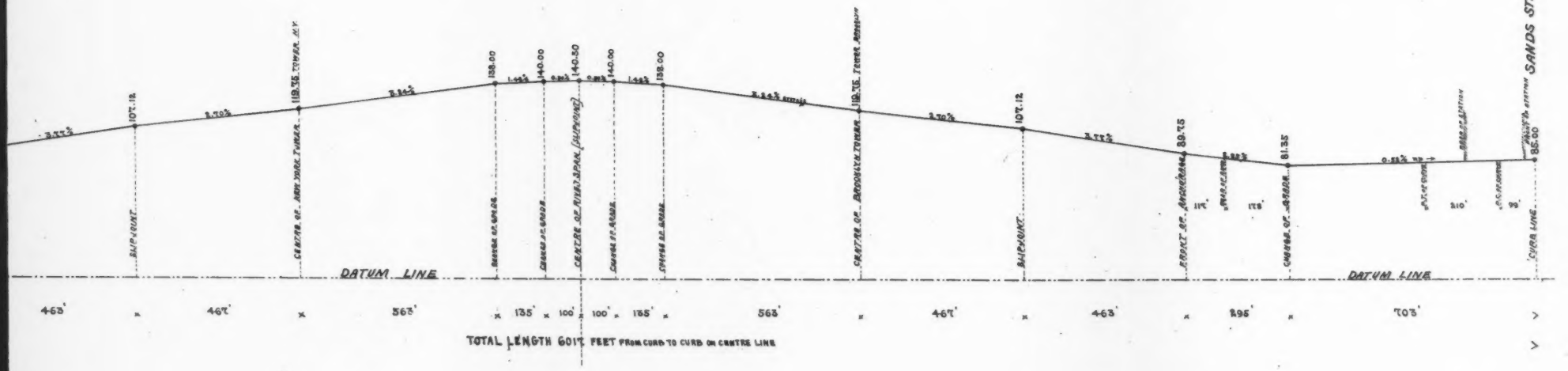


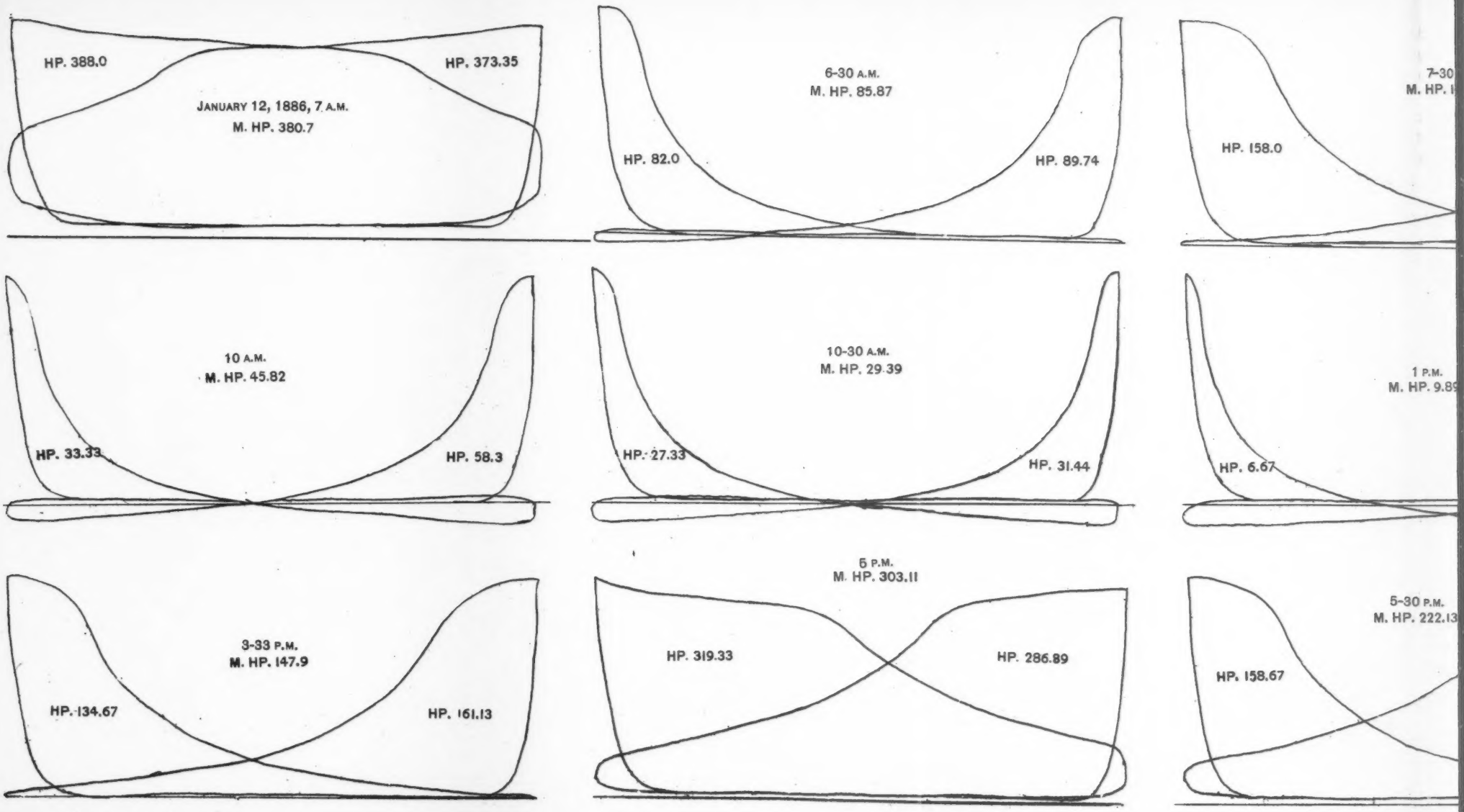
PLATE XXVI
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

PROFILE OF CABLE RAILWAY.

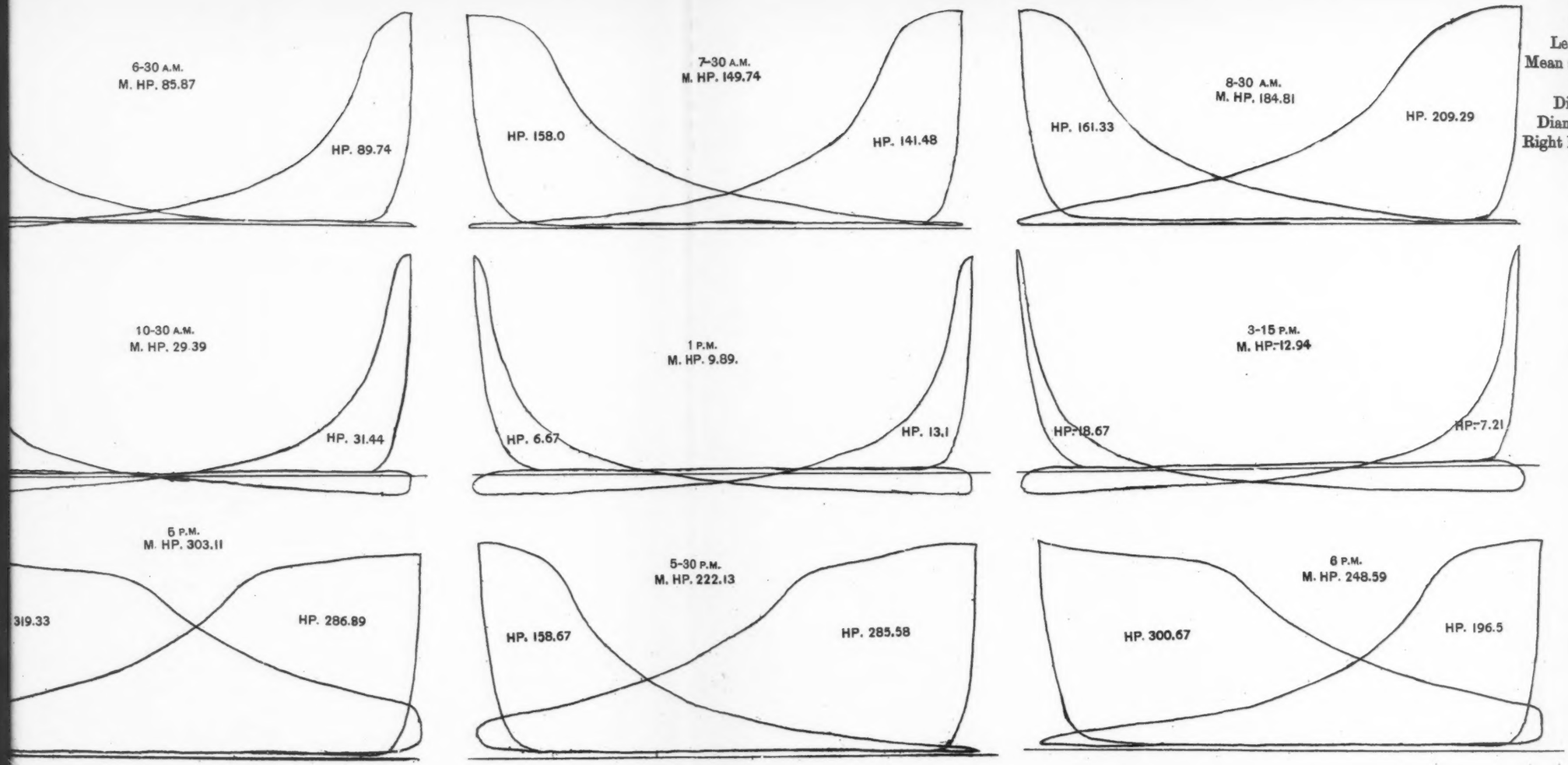


TOTAL LENGTH 6017 FEET FROM CURB TO CURB ON CENTRE LINE

INDICATOR CARDS FROM WESTERLY ENGINE
ALL TAKEN, EXCEPT AS NOTED, APRIL 26TH, 1886.



INDICATOR CARDS FROM WESTERLY ENGINE
ALL TAKEN, EXCEPT AS NOTED, APRIL 26TH, 1886.



Scale of pressure, 1–40.
Length of diagram 4.4 inches.
Mean speed of engine, 57 revolutions per minute.
Diameter of piston, 26 inches.
Diameter of piston rod, 3½ inches.
Right hand diagram is from crank end of cylinder.

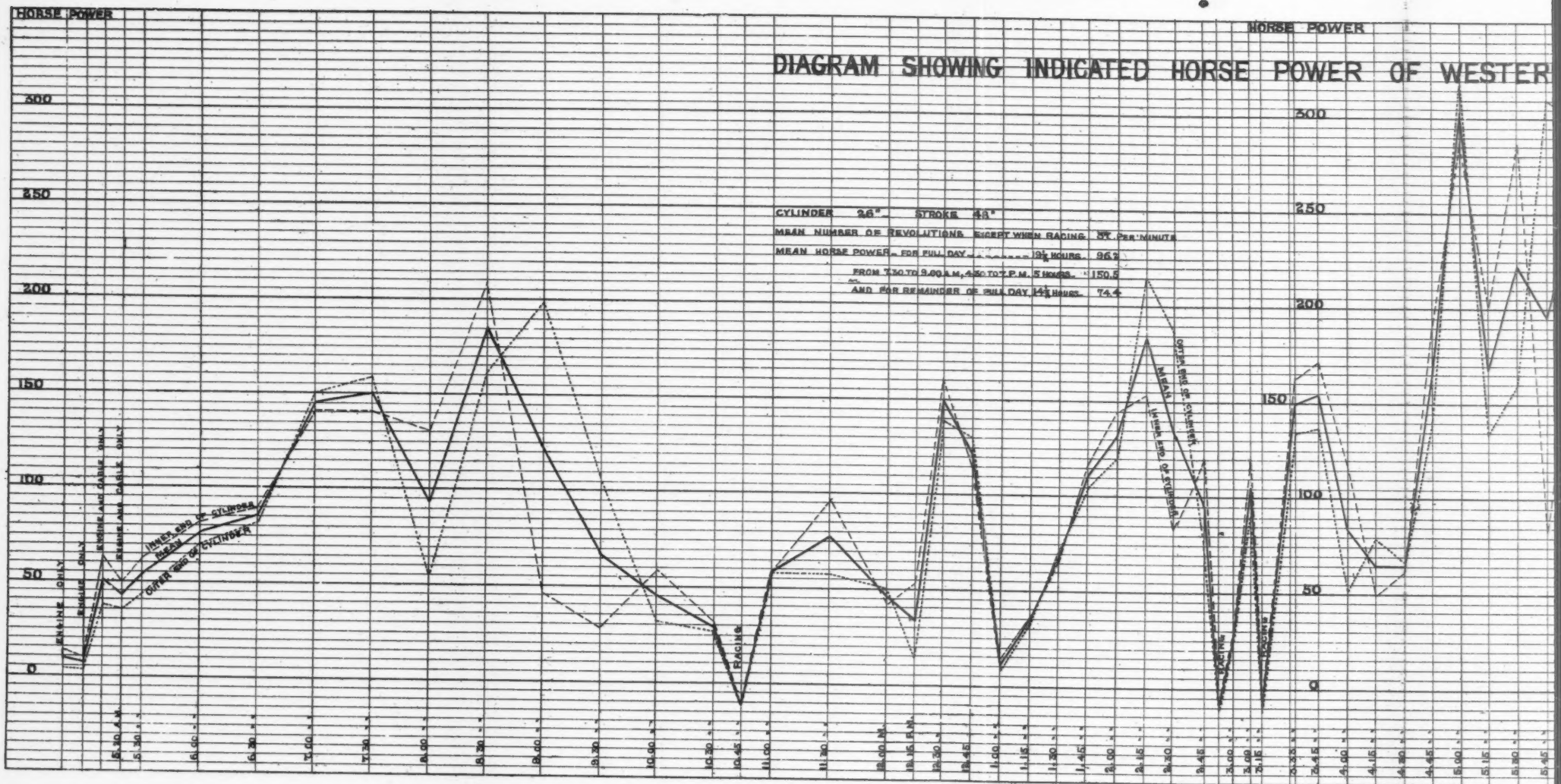
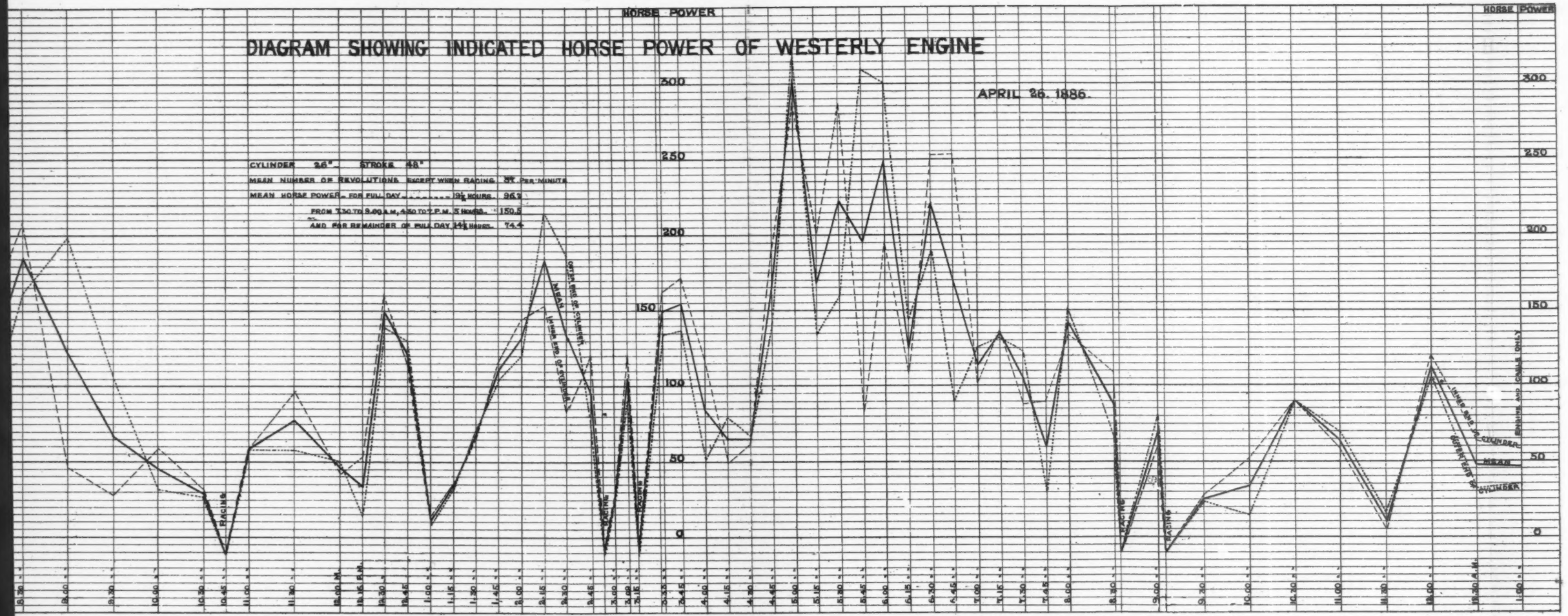

HORSE POWER
DIAGRAM SHOWING INDICATED HORSE POWER OF WESTER
CYLINDER 26" STROKE 48"
MEAN NUMBER OF REVOLUTIONS EXCEPT WHEN RACING 57 PER MINUTE
MEAN HORSE POWER FOR FULL DAY 19½ HOURS 96.2
FROM 7.30 TO 9.00 A.M. 4.30 TO 7 P.M. 5 HOURS 150.5
AND FOR REMAINDER OF FULL DAY 14½ HOURS 74.4
ENGINE ONLY
ENGINE ONLY
ENGINE AND CABLE ONLY
ENGINE AND CABLE ONLY
INNER END OF CYLINDER
MEAN
OUTER END OF CYLINDER
RACING
RACING
MEAN
INNER END OF CYLINDER
OUTER END OF CYLINDER
RACING
RACING
300
250
200
150
100
50
0
5.30 A.M.
5.30 "
6.00 "
6.30 "
7.00 "
7.30 "
8.00 "
8.30 "
9.00 "
9.30 "
10.00 "
10.30 "
10.45 "
11.00 "
11.30 "
12.00 M.
12.15 P.M.
12.30 "
12.45 "
1.00 "
1.15 "
1.30 "
1.45 "
2.00 "
2.15 "
2.30 "
2.45 "
3.00 "
3.08 "
3.15 "
3.33 "
3.45 "
4.00 "
4.15 "
4.30 "
4.45 "
5.00 "
5.15 "
5.30 "
5.45 "

PLATE XXVIII.
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY



FROM 4.56 TO 5.45 P. M. NOVEMBER, 1, 1883

PLATE XXIX
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY

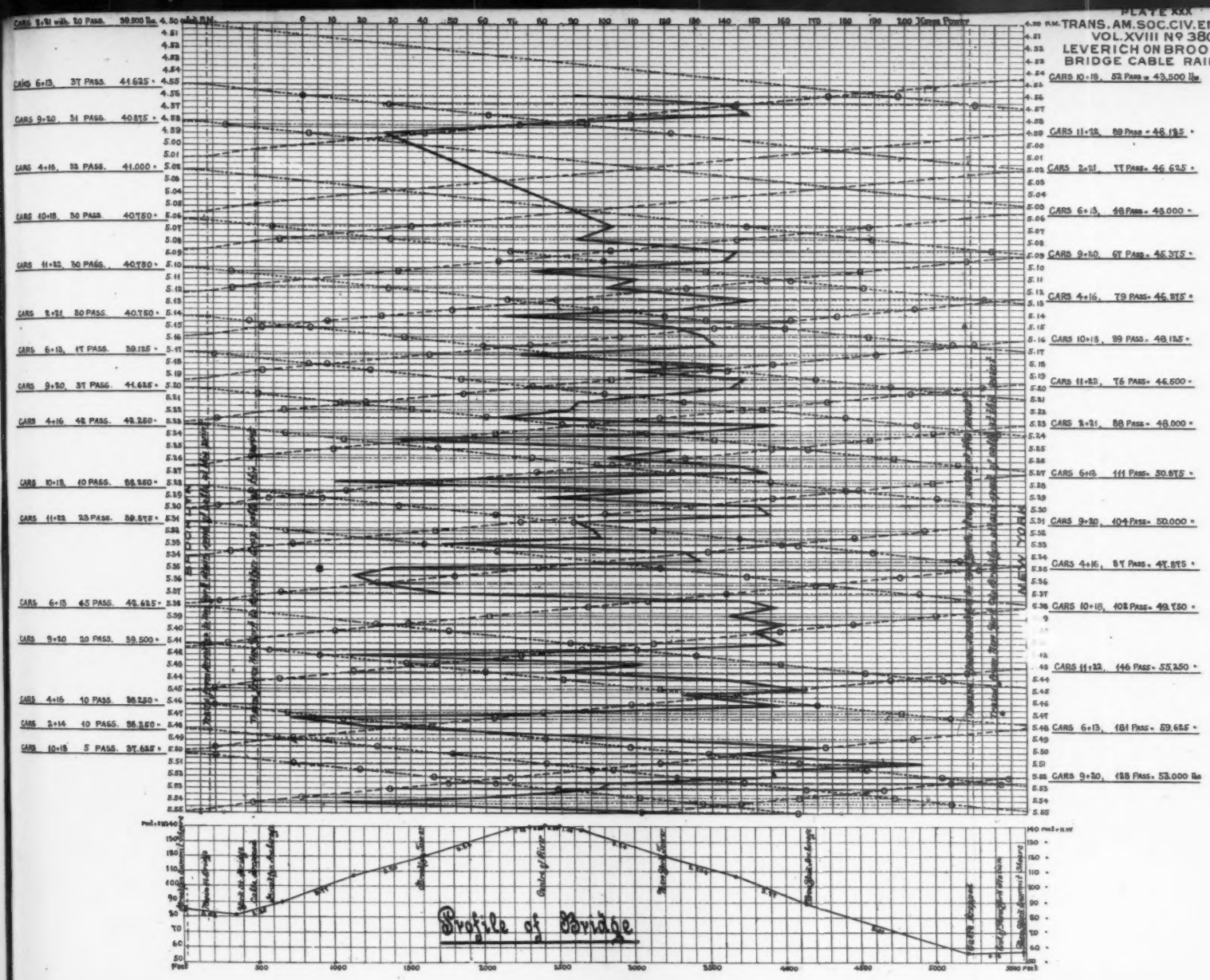
CAR 21 with 27 Pass. 23.975 lbs.
CAR 14 19 Pass. 23.500 "
CARS 40+16 " 46 Pass. 42.625 "
CARS 11+13 " 31 Pass. 40.975 "
CARS 9+21 " 38 Pass. 44.000 "
CARS 6+20 " 44 Pass. 36.750 "
CARS 4+23 " 46 Pass. 42.875 "
CARS 40+16 " 35 Pass. 41.375 "
CARS 11+13 " 34 Pass. 41.250 "
CARS 9+21 " 30 Pass. 40.750 "
CARS 6+20 " 46 Pass. 42.500 "
CARS 4+23 " 27 Pass. 40.875 "
CARS 10+16 " 42 Pass. 42.250 "
CARS 11+13 " 35 Pass. 41.375 "

CAR 21 with 50 Pass. 26.250 lbs.
CAR 23 45 Pass. 25.625 "
CAR 14 19 Pass. 24.125 "
CARS 40+16 " 111 Pass. 50.375 "
CARS 11+13 " 96 Pass. 46.200 "
CARS 9+21 " 127 Pass. 52.375 "
CARS 6+20 " 103 Pass. 50.125 "
CARS 4+23 " 113 Pass. 51.125 "
CARS 40+16 " 118 Pass. 51.000 "
CARS 11+13 " 133 Pass. 54.375 "
CARS 9+21 " 144 Pass. 55.000 "
CARS 6+20 " 145 Pass. 55.125 "

Profile of Bridge

PLATE XXX

TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 380.
LEVERICH ON BROOKLYN
BRIDGE CABLE RAILWAY.



CARS 2+21 with 20 PASS. 29.500 lbs.
CARS 6+13, 37 PASS. 41.625 "
CARS 9+20, 31 PASS. 40.875 "
CARS 4+16, 28 PASS. 41.000 "
CARS 10+18, 30 PASS. 40.750 "
CARS 11+23, 30 PASS. 40.750 "
CARS 2+21, 30 PASS. 40.750 "
CARS 6+13, 17 PASS. 39.125 "
CARS 9+20, 31 PASS. 41.625 "
CARS 4+16 42 PASS. 42.250 "
CARS 10+18, 40 PASS. 38.250 "
CARS 11+23, 25 PASS. 39.875 "
CARS 6+13 65 PASS. 42.625 "
CARS 9+20 20 PASS. 39.500 "
CARS 4+16 10 PASS 38.250 "
CARS 2+14 10 PASS. 38.250 "
CARS 10+18 5 PASS. 37.625 "

CARS 10+18, 52 Pass = 43,500 lbs
CARS 11+23, 89 Pass = 46.125 "
CARS 2+21, 77 Pass = 46 625 "
CARS 6+13, 48 Pass = 43.000 "
CARS 9+20, 67 Pass = 45.375 "
CARS 4+16, 79 Pass = 46.875 "
CARS 10+18, 99 Pass = 48.125 "
CARS 11+23, 76 Pass = 46.500 "
CARS 2+21, 88 Pass = 48.000 "
CARS 6+13 111 Pass = 50.875 "
CARS 9+20, 104 Pass = 50.000 "
CARS 4+16, 97 Pass = 49.875 "
CARS 10+18, 103 Pass = 49.750 "
CARS 11+23, 146 Pass = 55.250 "
CARS 6+13, 181 Pass = 59.625 "
CARS 9+20, 188 Pass = 53.000 lbs

Profile of Bridge